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DEPARTMENT OF ENGINEERING

THESIS

Cooling a telecommunication shelter using mini-eolic technology

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GRATITUDES

Gratitudes to Dr. Francesco Asdrubali

Francesco Bianchi & especially professor Giorgio Baldinelli

for helping me to develop this Thesis;

for their availability and the interest they put,

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and be part of this experience.

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so I could be able to enjoy of this life experience,

working head to head with the people that surrounded me

and helped me to develop this thesis.

I want to also thank my coworker Michele Renon,

who has behaved exemplarily as a working team mate and as a friend,

contributing with everything that was possible.

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CHAPTER 1: INTRODUCTION

REFRIGERATION OF A TELECOMMUNICATION SHELTER THROUGH RENEWABLE ENERGIES (SOLAR ENERGY AND EOLIC POWER). STUDY OF FEASIBILITY.

Refrigeration nowadays is needed in many applications throughout different sectors. Especially in electronic components where material temperature raises considerably and cooling is necessary in order to maintain the optimal working conditions for its correct function. Telecommunication shelters are no exception, and high temperatures are reached in their components. Therefore, there is an important develop to be done in this sector in order to reduce costs of energy for this process.

In this work we will consider two viable ways to minimize the heat of this electronic components. The first of them consists of an absorption machine fed by solar energy obtained by solar panels. The second option is based on a common refrigeration cycle with a compressor whose power will be obtained by mini eolic technology.

During this study we will analyze all the aspects to cover the second option, which is supplying the demand of a telecommunication shelter with a system based on eolic power. The first option was analysed by my coworker Michele Renon.

Italy is the world's sixth largest producer of wind power, with an installed nameplate capacity of 8,144 MW in 2012.

The energy from the 487 active plants accounts for the 19% of the renewable energy produced in Italy in 2010. The total energy produced in 2010 was 8,787 GWh, with an increase of 29% from the previous year.

On table 1, we can find the installed capacity growth, showing the annual increase of wind power capacity in Italy for the last years.

Year	Nameplate capacity		Plants	
	MW	change	number	change
2000	363	-	55	-
2001	664	82.92%	81	47.27%
2002	780	17.47%	99	22.22%
2003	874	12.05%	107	8.08%
2004	1,131	29.41%	120	12.15%
2005	1,639	44.92%	148	23.33%
2006	1,908	16.41%	169	14.19%
2007	2,714	42.24%	203	20.12%
2008	3,538	30.36%	242	19.21%
2009	4,898	38.44%	294	21.49%
2010	5,814	18.70%	487	65.65%
2011	6,936	19.30%	807	65.71%
2012	8,144	17.42%		

Table 1. Installed wind capacity in MW along the years in Italy [1].

1.1 WIND CONDITIONS IN ITALY:

Is Italy a good place for eolic? Well, the annual media wind distribution map in Italy goes as follows in figure 1.

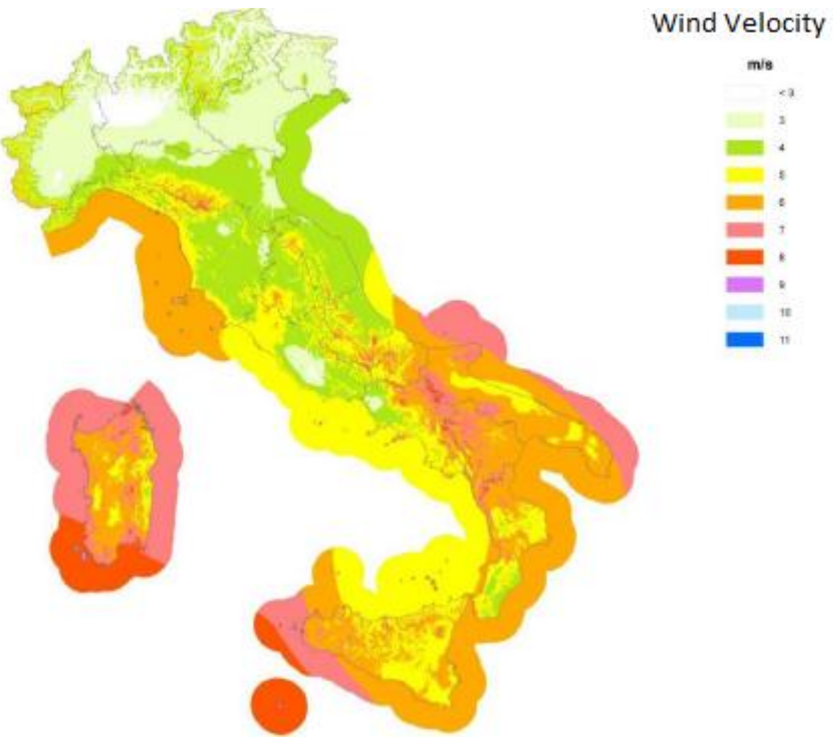


Figure 1. Wind distribution in Italy.

As we can see, the best places to place our eolic turbine is in the south of Italy, where we can find higher wind velocities. As well as we can find some other places in the center where we could get wind velocities around 6 m/s.

We will consider Perugia and other places in Italy (such as Puglia) to build our telecommunication shelter.

According to the University's Wind Energy Report, 3% of the Italy's land area has average wind speeds greater than 6 m/s or good to excellent wind, 37% has average wind speeds from 4 m/s to 6 m/s or sites with good wind. The report quotes the Italian wind energy association (Associazione Nazionale Energia dal Vento), that Italy has the potential for 1,000 MW of small wind capable of generating 1.5-2 TWh per year. For comparison, solar PV generated more than 10 TWh in 2011.

Based on the CNR, the centro-meridional cost region and the islands, and also some parts in Liguria, are the most suitable for the eolic power.

1.2 THE DEMAND:

Our costumer, the Enterprise IMET needs to refrigerate a shelter for telecommunication devices with the help of the Enterprise RIGEL.

Temperature Conditions

The shelter shall be designed and equipped with an environmental control system consisting of air conditioning and heating capable of maintaining the inside temperature under operating conditions, plus sensible and latent heat gains from personnel, at 20°C (75°F) (+) 3°C (5°F). The internal temperature shall not rise above 30°C (84°F) with an outside ambient temperature of 45°C (110°F) (temperatures are to be maintained while the equipment is operating at 75% duty cycle) and shall not fall below 18°C (65°F) with an outside ambient temperature of -35°C (-30°F) while equipment is OFF.

1.3 ASPECTS TO BE CONSIDERED WHEN REALIZING THIS PROJECT:

- Since the weather is changing during the seasons of the year, there is a different need of power for cooling. As obvious, on winter there is less heating load than in summer.
- We will consider free cooling options for the cooler months of the year. This option introduces air from the outside when the temperature outside is lower than the one desired on the inside (20°C).
- The effect of radiation affects negatively during the hole year on the load, causing it to be lightly greater, but, as we will analyze further, this effect can be negligible.
- For analysis purposes, we can assume that the telecommunication shelter works at approximately the same operative point all day, all the year. Therefore, there is a constant intern load produced by the machines to be refrigerated. This is, the load to be refrigerated on the shelter was calculated in steady state, and so, fluctuations were not considered
- As obvious, weather magnitudes such as sun hours or wind velocity are very fluctuating all over the day and the year. Therefore, there is a natural need to use an auxiliary system that provides the required demand. This option will be covered by supplying the demand with electricity obtained by the network or by the addition of batteries into the system.
- COP value for our refrigeration machine is considered constant at a value of 2.5.
- An unique value for buying electricity to the grid is considered, at 0.1835 €/kWh.

1.4 THE AIM of the thesis.

The aim of this thesis is therefore, to find the most economic and efficient way for cooling the load (refrigeration load) of a telecommunication shelter. As we will analyze in chapter 5, this load takes a value of approximately 30 MWh a year. Although for the dimensioning of the system we will take into account 60 MWh, which is the expected load in the future for the shelter.

In order to do this we will analyze and contrast the possibility of obtaining the energy we need to create a refrigeration cycle (which will be analyzed further) with eolic power (to create electricity) with the conventional option of feeding the cycle with electricity obtained directly from the grid.

1.5 CHARACTERISTICS OF THE SHELTER:

We have a 10.5 meter square shelter, with an approximate load of 0,5 kWh/m^2.

In the future, this load will be duplicated, therefore, in order to choose the size and the dimension of the components (batteries and wind turbines), we will duplicate the actual values obtained.

Dimensions of the shelter are the followings shown on figure 2:

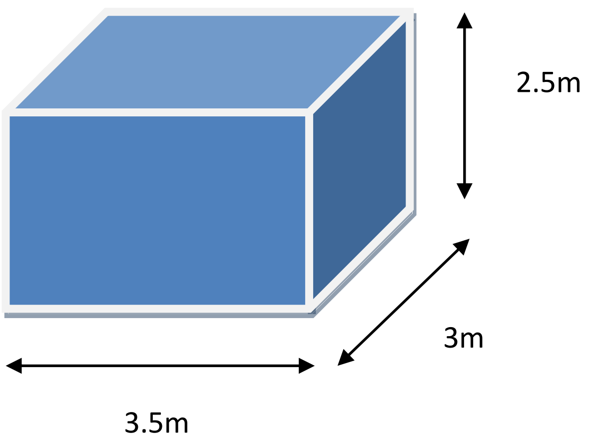


Figure 2. Dimensions of the shelter.

CHAPTER 2: KNOWING TECHNOLOGIES

On this chapter we will analyze how does the mini-eolic power works to obtain electrical power.

MINI-EOLIC POWER:

What is mini-eolic? [3]

It's the Energy created by aero-generators that used wind as a source of energy, with a power approximately lower than 100 kW.

The reason of the limitation on 100 kW is primarily due to the fact that IEC 61400-2 norm establishes as small aero-generators those whose swiping area is lower than 200 m^2, which brings us to equipments over 50 kW of nominal power (approximately). Limitation is also due to the regulation for lower tension, which establishes the power limit up to 100 kW.

In many countries like the Netherlands, UK or US the mini-eolic power is already a reality. The aim is to obtain between 30 and 40% the electrical energy of the country (for 2050) through installations of micro-generation implanted on buildings, primarily fed by mini-eolic and solar photovoltaic.

What the eolic technology basically does is to capture the kinetic energy from the wind and transform that into electric power for later multiple uses. In order to achieve this conversion, several steps and components are needed, and this is what we will explain.

Wind conditions depend on many atmospheric factors, but what causes the wind to blow is the pressure differences located in the atmosphere. This causes the air to travel from places of greater pressure into places with smaller pressure. So… how can we catch this natural phenomena energy absolutely free of cost?

Figure 3. Typical wind turbine.

Wind turbines are built to take advantage of the local pressure difference caused on the blades of the eolic tower. The blades represent the active part, and their design, as we can see in figure 3, is built in such a way that they induce a pressure difference on the wind while this passes through them. By deflecting the direction of the wind, we are able to induce a difference of velocity on it, directly causing a pressure differential on the blades that induces themselves to move in a rotational way.

Now that we have an induced rotation movement on the blades, what's next?

We already captured the mechanical movement we wanted in order to go to the next component, which is no other than the generator.

The edge of the blades spins into the core of an electricity generator as we can see in figure 4, converting the mechanical movement into electricity itself. This is possible due to the electromagnetic fields created inside the core of the generator, inducing on it the electricity in a 3-phase way.

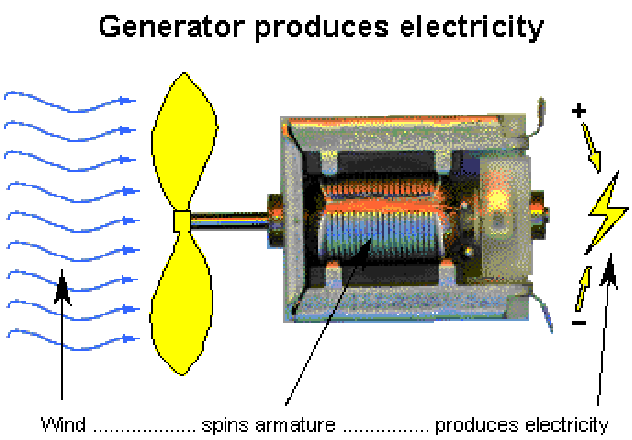


Figure 4. Generator on a wind turbine.

Once the electricity is obtained, this will be used to feed a compressor in an energetic cycle as the one showed in figure 5.

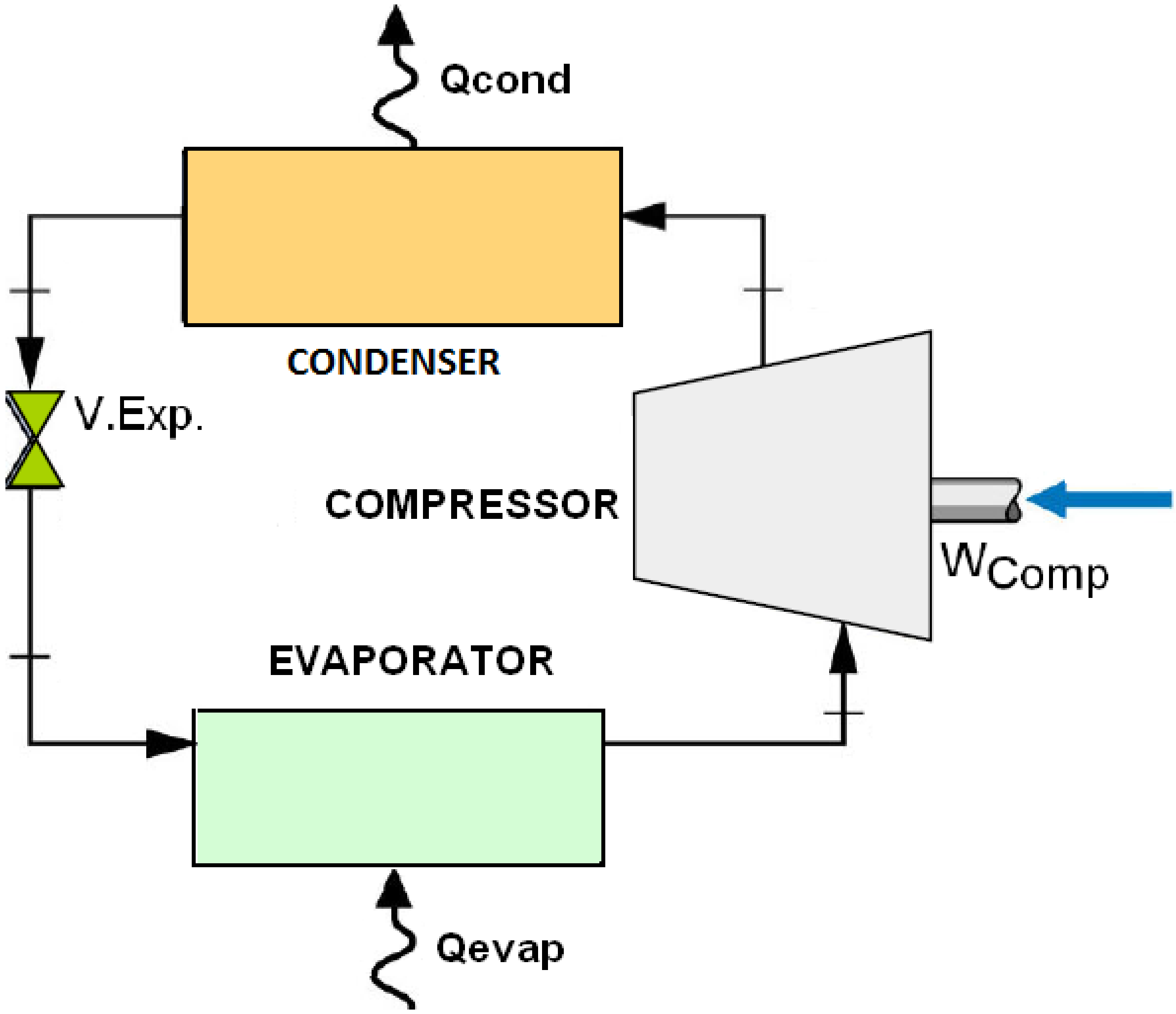


Figure 5. Scheme of the cycle to be used in order to obtain the cooling load for the shelter.

As we can see, Qevap is the amount of heat that we need to take out of the telecommunication shelter (the refrigeration load). Wcomp is the amount of power that we need to introduce into the system in order to keep the cycle going. And finally Qcond is the amount of heat that we need to take out of the cycle, which will be expelled into the environment for example through a heat exchanger with the cool side as a river.

Note: If we also take advantage of the heat extracted in the condenser (Qcond) we would be as well developing an even more efficient cycle which is called cogeneration.

CHAPTER 3: KNOWING THE MARKET

During this chapter we will mention the different wind turbine products that we can find on the market, in order to pick one or more of them for our project to analyze the cost of each them.

In order to choose which of the products are good for our project we will consider three different cases depending on the connection with the network.

First of all, we'll mention the different configurations of an eolic installation with the grid:

[4]*Grid off:* In this type of configuration, the installation doesn't have any connection to the grid. The energy produced is consumed by our own application at the same time as produced, and the excess of energy gets stored in batteries for its further use. This type of configuration is used in those places where the electricity from the grid is not present like for example remote mountains huts.

Grid on: In this type of configuration, the installation is connected to the grid. We'll find three different connections inside this group.

- Net metering ("scambio sul posto"): The plant is connected to the grid in an interdependent way with respect to the installation of our application. The energy produced is consumed at the moment, and the excess goes into the grid for further use. In this type of configuration the grid takes into account the amount of energy sent on it and then the same amount of it can be delivered later to the application when the wind is not blowing. In a certain way, the grid acts as a huge battery for the application, delivering the amount of energy we plug into it. In case we take from the grid more energy than the one injected on it, we'll pay for the difference.

Net metering policies can vary significantly by country and by state or province: if net metering is available, if and how long you can keep your banked credits, and how much the credits are worth (retail/wholesale). Most net metering laws involve monthly rollover of kWh credits, a small monthly connection fee, require monthly payment of deficits (i.e. normal electric bill), and annual settlement of any residual credit. Unlike a feed-in tariff (FIT) or time of use metering (TOU), net metering can be implemented solely as an accounting procedure, and requires no special metering, or even any prior arrangement or notification [5]. Net metering is a policy designed to foster private investment in renewable energy

With net metering, customers are billed for their net power usage. If the customers produce more power than they use in a month, the utility maintains a credit to be used to offset future net usage. For example, assume that in June, Dave and Sally produced 100€ worth of solar power in excess of their monthly usage. July was a rainy month so they used 120€ more power than their solar panels produced. Their utility company offsets their credit balance of 100€ and sent Dave and Sally a bill for 20€.

This system is typically used for small plants of renewable energies, allowing them to put into the grid the excess of energy produced for further use.

Due to the high growing in the market of renewable energies like eolic and photovoltaic, net metering has begun to be a regulated activity in many countries all over the world, being now a reality in countries like Germany, Italy, Denmark, Japan, Australia, USA, Canada, Mexico and others.

Simplified Purchase and Resale Arrengements:

- Totally sold: The plant is connected to the grid in an independent way with respect to the installation of our application. All the energy produced is sold to the grid (ENEL, Enia, Hera, ecc.). This configuration is most used in big plants. All electricity needed is directly purchased to the grid.

- Partially sold: The plant is connected to the grid in an interdependent way with respect to the installation of our application. The energy needed for our application is used in our installation and the exceeds are sold into the grid. When needed electricity can be purchased to the grid.

Case 1: One eolic turbine plugged into the grid in a partial or in a total connection (without batteries) supplies the peak of demand (4.7 kW) and exceeds it. Therefore, we choose an eolic turbine of 20-50 kW. The energy that exceeds will be plugged in the network. In case we do a total connection, all the energy goes directly to the network and the energy needed to supply our demand is taken from the network as well.

Case 2: One eolic turbine plugged into the grid in a partial connection (without batteries) supplies the peak of demand (4.7 kW). Therefore, we choose an eolic turbine of 5-8 kW. The energy that exceeds will be plugged in the network.

Case 3: One eolic turbine plus batteries (not plugged into the grid) in a grid off supplies the peak of demand (4.7 kW). Therefore, we choose an eolic turbine of 5-8 kW. The energy will charge a battery of approximately the same power and this will supply the electricity needed for the load.

Note: In chapter 5 we will explain the reason of each of the cases and we will explain why the values of the powers are those.

On a first research into the market we can find the ESPE Group enterprise[6]. ESPE Group offers two models for eolic plants, the ESPE FX 18 and ESPE FX 21. Both models offer a maximum power of 60kW, which is way off the power we need but we will need to consider this option as well in the economic analysis since it stills covers the power range to be considered as mini-eolic.

The ESPE FX 18 offers:

Security systems

As many as 4 technologies for the utmost safety, compliant with the standards required by IEC 61400-1.

Negative Control Device cantilever application of the blades by means of storage of potential elastic energy.

Negative Brake braking of rotor rotation by means of Disc brakes that store up elastic energy.

Rotor lock secure mechanical lock of the rotor due to interference.

Active yaw control turbine direction management perpendicular to wind direction.

General specifications

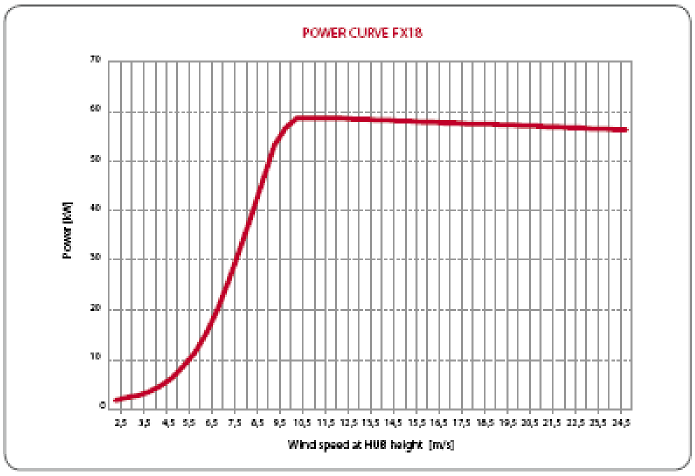
Rated power	60,00 kW
Cut-in wind speed	3 m/s
Rated wind speed	10,5 m/s
Cut out wind speed	25 m/s
Rotor diameter	18 m
Hub height	Up to 30.0 m
Wind classes	IEC, IIA
Standard Conformity	CEI EN IEC 61400-1

Turbine	
Turbine Concept	Direct-drive, variable speed, variable pich control, passive safety systems
Direction of rotation	Anti-Clockwise
Number of blades	3
Swept area	254 m²
Blade material	Fibreglass (apoxy resin)
Rotation speed	70 rpm (variable from 20 up to 70)
Pitch control	Variable pich control

Generator	
Type of Generator	Synchronous induction with permanent magnet

Tower	
Type	Tubular steel

Movement	
Breaking system	Active Yaw Control



m/s	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5	10	10,5	11	11,5	12	12,5	13	13,5
kW	0	0,61	1,07	1,83	2,99	4,71	7,11	10,3	14,38	19,43	25,45	32,24	39,29	46,36	54,26	58	60,00						59,8
m/s	14	14,5	15	15,5	16	16,5	17	17,5	18	18,5	19	19,5	20	20,5	21	21,5	22	22,5	23	23,5	24	24,5	25
kW	59,7	59,6	59,5	59,4	59,3	59,2	59,1	59	58,9	58,8	58,7	58,6	58,5	58,4	58,30	58,2	58,1	58	57,9	57,8	57,7	57,6	57,5

Meanwhile the FX 21 characteristics are:

m/s	2,5	3	3,5	4	4,5	5	5,5	6	6,5	7	7,5	8	8,5	9	9,5	10	10,5	11	11,5	12	12,5	13	13,5
kW	0,50	0,78	1,37	2,34	3,84	6,05	9,13	13,22	18,46	24,94	32,67	41,37	50,43	59,5	60,00								59,8
m/s	14	14,5	15	15,5	16	16,5	17	17,5	18	18,5	19	19,5	20	20,5	21	21,5	22	22,5	23	23,5	24	24,5	25
kW	59,7	59,6	59,5	59,4	59,3	59,2	59,1	59	58,9	58,8	58,7	58,6	58,5	58,4	58,3	58,2	58,1	58	57,9	57,8	57,7	57,6	57,5

Security systems

As many as 4 technologies for the utmost safety, compliant with the standards required by IEC 61400-1.

Negative Control Device cantilever application of the blades by means of storage of potential elastic energy.

Negative Brake braking of rotor rotation by means of Disc brakes that store up elastic energy.

Rotor lock secure mechanical lock of the rotor due to interference.

Active yaw control turbine direction management perpendicular to wind direction.

General specifications

Rated power	60,00 kW
Cut-in wind speed	2,8 m/s
Rated wind speed	9,5 m/s
Cut out wind speed	25 m/s
Rotor diameter	20,4 m
Hub height	Up to 30.0 m
Wind classes	IEC, IIA
Standard Conformity	CEI EN IEC 61400-1

Turbine	
Turbine Concept	Direct-drive, variable speed, variable pich control, passive safety systems
Direction of rotation	Anti-Clockwise
Number of blades	3
Swept area	326 m²
Blade material	Fibreglass (apoxy resin)
Rotation speed	70 rpm (variable from 20 up to 70)
Pitch control	variable pich control
Generator	
Type of Generator	Synchronous induction with permanent magnet
Tower	
Type	tubular steel
Movement	
Breaking system	Active Yaw Control

After seeing some characteristics we will mention some important features about them:

- Cut-in wind speed: This wind speed indicates the velocity at which the eolic turbine starts producing energy. It normally takes a value from 2m/s to 3m/s.

- Rated wind speed: It's the value for the wind speed in which the eolic turbine get's it's maximum value. After this value most of eolic turbines show an approximate constant value for the power obtained.

- Cut-out wind speed: It's the value at which the wind turbine stops producing energy. After this value the eolic installation is not able to take energy out.

- Variable pitch control: The eolic turbine blades can be rotated around their long axis to change their pitch angle. This helps to take advantage in a more efficient way the extraction of energy.

- Active Yaw Control: The yaw system of wind turbines is the component responsible for the orientation of the wind turbine rotor towards the wind.

Both products will be considered for case 1.

Figure 6. Model Bee 800

Another manufacturer that we can find in the market is **Bornay [3]**.

Focusing on the minieolic branch one of the most basic aero-generators they have is the **Bee 800**.

These are pefect to satisfy a demand of an electrical home installation (see figure 6), but enough for our demand?

The installation is composed by solar panels on the rooftop, an aerogenerator, and inverter, a regulator and batteries.

The battery stores the energy obtained from the solar panels and the aerogenerator. The recommended autonomy of it is 3 days.

Figure 7. Bornay Bee 800 model uses for electrical home installation.

Characteristics for this model are the followings:

Wind velocity:

Cut-in speed	3,5 m/s
Nominal power speed	12 m/s
Maximum wind velocity	60 m/s

Electrical specifications:

Alternator	Three phase permanent magnets
Nominal power	800 W
Voltage	12, 24, 48 v
RPM	@ 500
Survival	12v 70 Amp 24v 35 Amp 48v 18 Amp

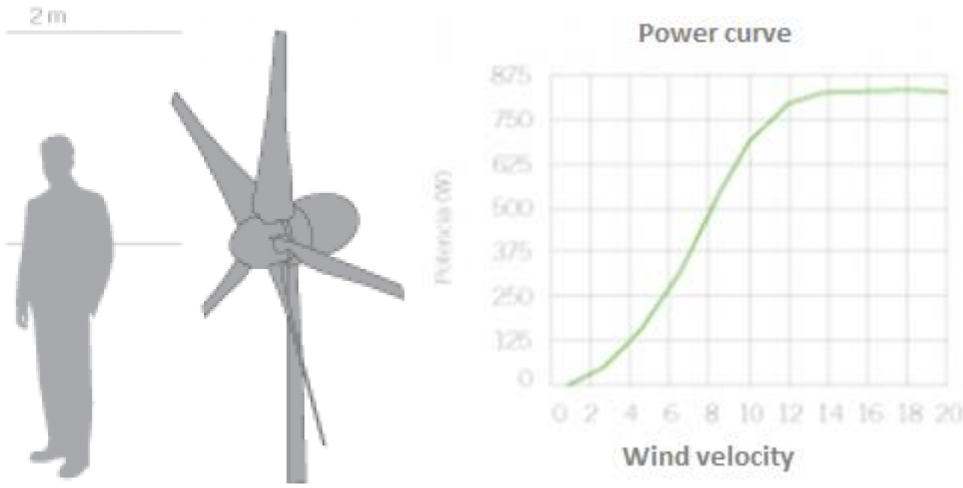


FIgure 8. Dimensions and power curve for Bee 800

As we can see, the maximum power we are able to obtain with this aerogenerator is very low for our purpose (800 W vs. 5kW). Therefore, this model is not useful.

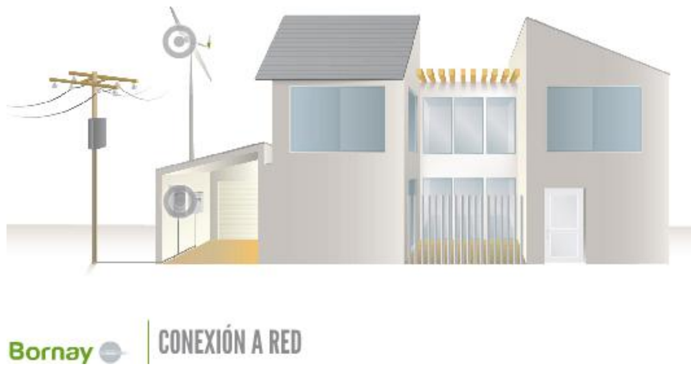
We check out then other models like the **Bornay 600**. But in this case the nominal power of it is 600W, which is not enough for our purpose. The models **Bornay 1500** and **Bornay 3000** have the same problems (1.5 kW and 3kW of nominal power respectively).

We analyze then, the top model of this gamma, which is the **Bornay 6000**.

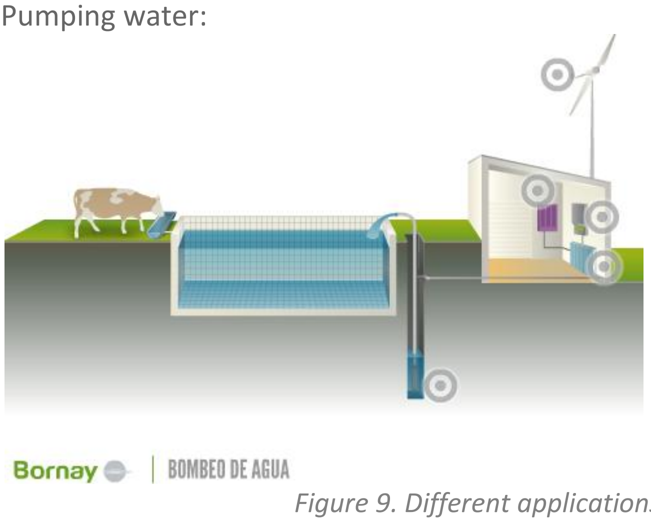
This model can be use for the applications shown in figure 9.

Satisfy the electrical demand of a house.

Network connection:



Pumping water:



And telecommunications

Figure 9. Different applications for the model Bornay 6000.

Characteristics for this aerogenerator are displayed in figure 10:

Technical specifications

Number of blades	3
Diameter	4 mts
Material	Fiberglass and carbon fiber
Direction of rotatio	Counterclockwise
Contol systems	1) Electronic regulator 2) Passive by tilting

Electrical specifications

Alternator	Three phases permanent magnet
Magnets	Neodymium
Nominal power	6000 W
Voltage	48, 120 v
RPM	@ 600
Regulator	48v 150 Amp. 120v. Grid connection

Physical specifications

Windturbine weight	107 kg
Regulator weight	18 kg
Packaging Dimensions - weight	120 x 80 x 80 cm - 149 Kg 260 x 40 x 15 cm - 22 Kg
Warranty	3 years

Performance, windspeed

For turn on	3,5 m/s
For nominal power	12 m/s
For automatic brake system	14 m/s
Survival	60 m/s

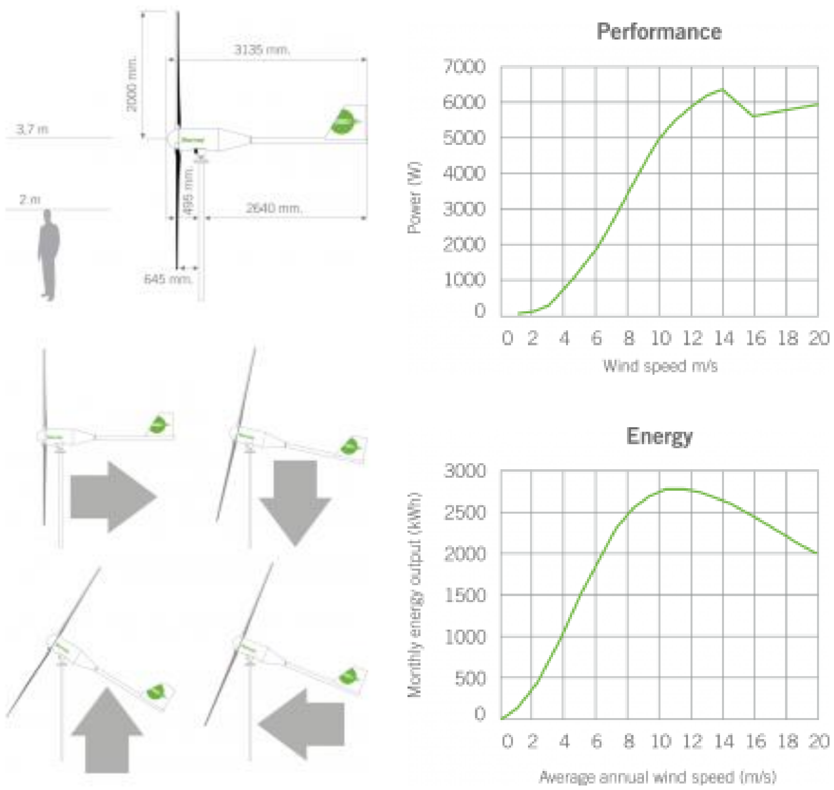


Figure 10. Dimensions, features, power curve and energy output for Bornay 6000.

As we can see, it offers a nominal power of 6kW. Power that could be considered in cases 2 and 3. As well, its working velocities are good for the case we are considering in Italy. We can also see that this model offers the variable pich control, allowing it to position to the wind the best possible in order to obtain the most amount of energy possible from it.

The company **RENOVA WIND ENERGY**[7] also offers products for minieolic turbines.

Among them we can find products such as

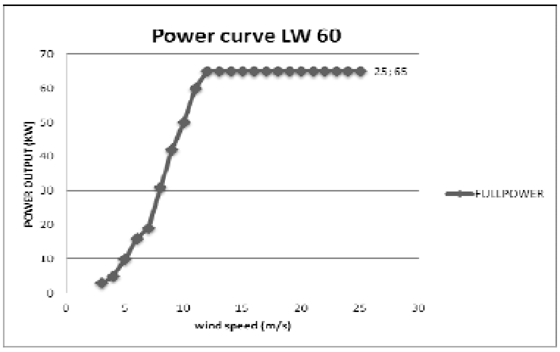
MISTRAL 10Kw
WINDTECH 20 Kw
WINDTECH 30 Kw

LARGERWEY 60KW
VESTAS V17 60KW
BONUS 23/60 KW
NORDTANK16/60 KW RIGENERATA

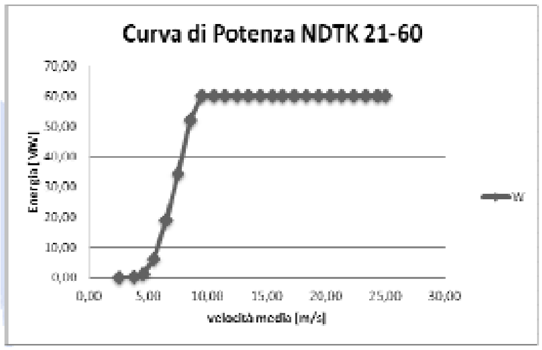
NORDTANK 21-60 Kw
NORDTANK 25-60 Kw
VESTAS V20-60 Pitch attivo

The models with the respective power curve are as follows:

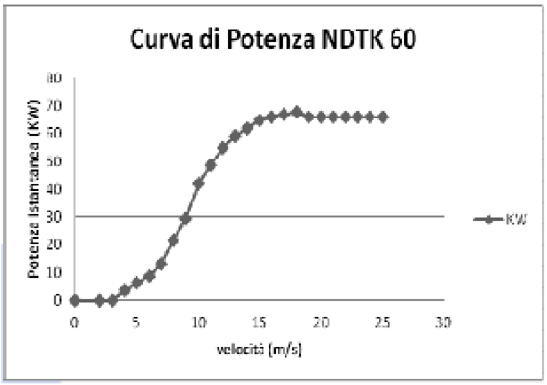
Largerwey 18-60kW.



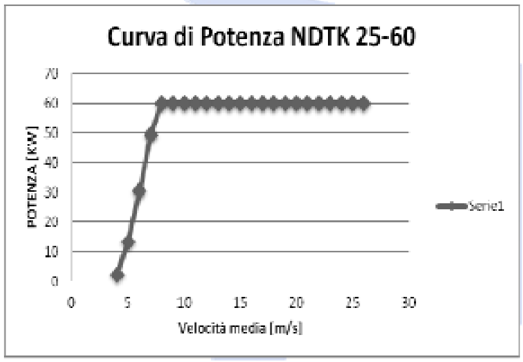
Nordtank 21-60kW.



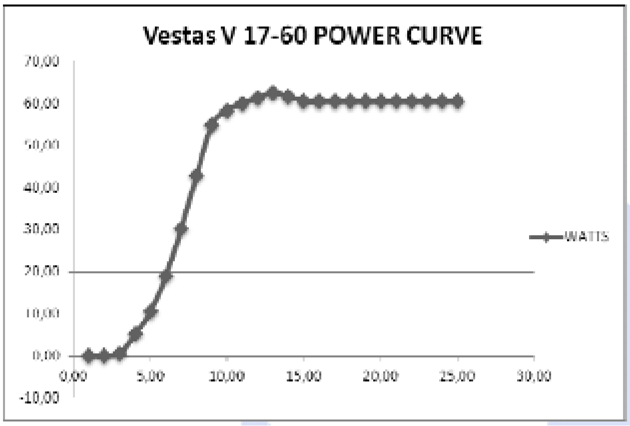
Nordtank 16-60kW.



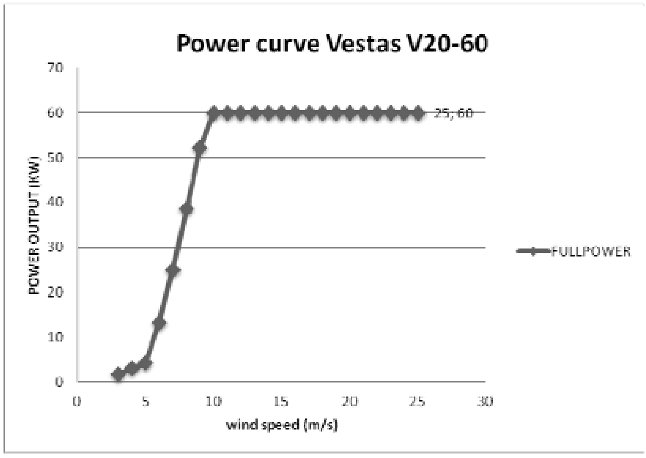
Nordtank 25-60kW.



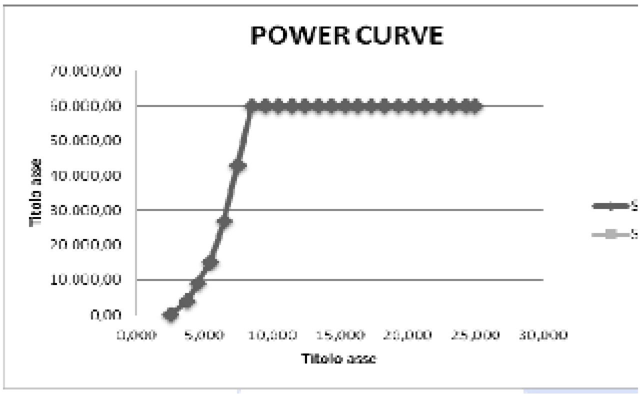
Vestas V17-60kW.



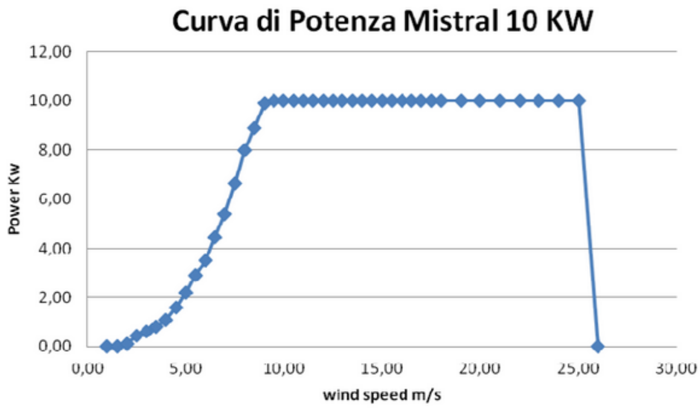
Vestas V20-60kW.



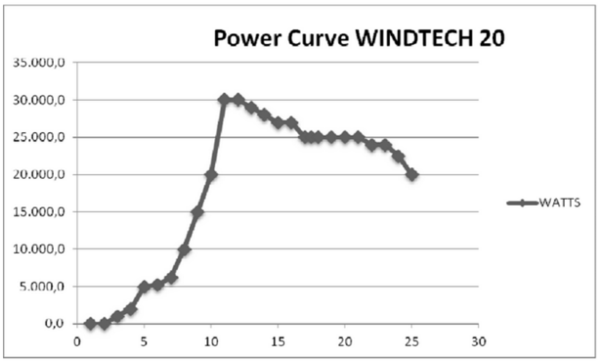
Bonus Wind 23-60 and 25-60.



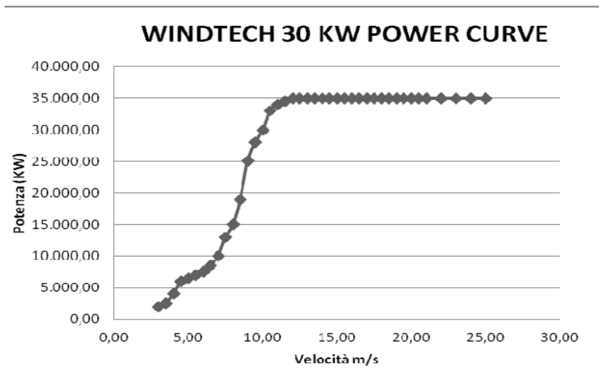
MISTRAL 10KW



WINDTECH 20KW



WINDTECH30KW



For this company, as we can see, we have a lot of varieties on power curves for each model. In chapter 5 we will study which of them is among the best options to our application.

FREE WIND ENERGIA[8] is an Italian enterprise. This enterprise has so far built a couple of minieolic installations in the south of Italy, at Puglia. Although this two installations are far away from our power purpose we are still inside minieolic range of power.

Mini-eolic system "San Marchitto"

Power:	60 kW
Height to the hub:	36 m
Rotor diameter:	16.5 m
Site:	City of Orta Nova (FG) - Apulia
Location:	San Marchitto
Coordinates:	41 ° 16'34 .01 "N - 15 ° 38'08 .34" E
Wind turbine Manufacturer:	Eolart - Comecart spa
Made by:	Free Wind Ltd.
Owner installation:	Free Wind Ltd.
Ready for use:	14/10/2011

Mini-eolic system "Passo d'Orta"

Power:	60 kW
Height to the hub:	36 m
Rotor diameter:	16.5 m
Site:	City of Orta Nova (FG) - Apulia
Location:	Step Orta
Coordinates:	41 ° 19 '36.56 "N - 15 ° 45' 54.53"
Wind turbine Manufacturer:	Eolart - Comecart spa
Made by:	Free Wind Ltd.
Owner installation:	Free Wind Ltd.
Ready for use:	29/09/2011

Figure 11. Projects developed by Free Wind

When looking into minieolic turbines, we are also interested in products manufactured by **ROPATEC** [9].

This Italian company offers three different models. The T20pro (&T20proS), the T30pro (&T30proS) and the T-vision.

The T-vision offers a nominal power of 3kW, useless for our application. On the contrary, the T30pro offers a nominal power of 30kW, which can be considered for case 1.

Considering this company as a possible supplier for our purpose, we would be considering the T20pro and T30proS. T20 offers the following:

TECHNICAL DATA

Turbine and generator manufacturer		ROPATEC
Turbine model		**T20*pro***
Nominal power		20 kW
Wind speed		
	Cut-In	ca. 4 m/s**
Start-up CUSTOMIZED	CUT-OUT	22 m/s
Start-up STANDARD	CUT-OUT	17 m/s
	Wind class according to IEC 61400-2	class III
Generator		Direct driven permanent magnets
Turbine wings material		Carbon and glass fiber
Turbine diameter		10 m
Wing length		10 m
Overspeed control		Safety PLC controller SIL-3 (electrical and hydraulic brake)
Noise		
	Value	ca. 40 dB
	Wind speed	8 m/s
	Distance from pole	30 m

Power curve***

Wind Speed (m/s)	STANDARD *Power* (W)	CUSTOMIZED *Power* (W)
3	59	**59**
4	620	**620**
5	2100	**2100**
6	4000	**4000**
7	6800	**6800**
8	9500	**9500**
9	13400	**12500**
10	18300	**15000**
11	20000	**16500**
11,5	20000	**18000**
12	20000	**19000**
13	20000	**20000**
14	20000	**20000**
15	20000	**20000**
16	20000	**20000**
17	-	**20000**
18	-	**20000**
19	-	**20000**
20	-	**20000**
21	-	**20000**
22	-	**-**

The turbine can be additionally calibrated according to the site.

Support

Pole height	Standard	24 m class III

Weight

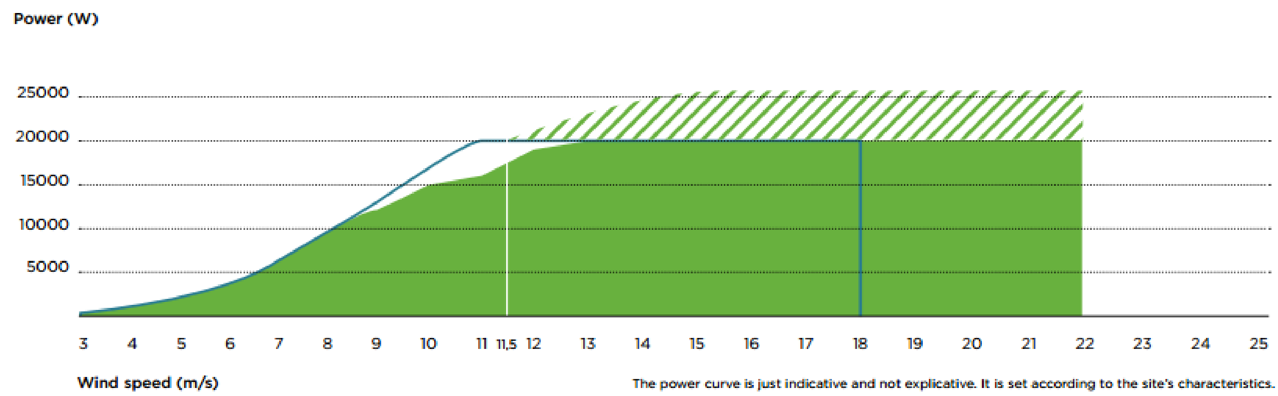
Turbine (without pole)	ca. 3500 kg
Monitoring system	SDMR / SCADA (optional)
Operating temperature	-20°C/+55°C
Operating altitude	≤ 2000 m AMSL

AEP *
Distribution K = 2
IEC 61400-12-1

Annual average wind	STANDARD kWh/year	CUSTOMIZED kWh/year
5,5 m/s	52000	54000
6,0 m/s	61000	64400
6,5 m/s	69000	74000
7,0 m/s	76000	82000

To consider this turbine as an option it is always very important to know its power curve for further analysis. The power curve for the T20 pro is the one showed in Figure 12.

Power curve



The data reported reflect ideal work conditions; they are subject to change in relations to external factors such as temperature, altitude, atmospheric pressure, turbolence level, humidity and presence of obstructions.

* Annual Energy Production
Strongly depending on the wind shear and distribution factor.

** This value is an everage of of 10 minutes.

*** The data correspond to a laminar wind.

Figure 12. Power curve for the T20pro wind turbine.

The graphic that delineates the blue line are the values for the standard T20pro. Instead, the one in green is for the T20pro customized; noticing that for this last one we would be able to obtain even more energy from the wind since we are covering a bigger and higher range of velocities to produce energy.

Characteristics for the T30proS are instead:

TECHNICAL DATA

Turbine and generator manufacturer	ROPATEC
Turbine model	***T30pro***
Nominal power	30 kW
Wind speed	
Cut-In	ca. 4 m/s**
Start-up — CUSTOMIZED — CUT-OUT	26 m/s
Start-up — STANDARD — CUT-OUT	17 m/s
Wind class according to IEC 61400-2	class III
Generator	Direct driven permanent magnets
Turbine wings material	Carbon and glass fiber
Turbine diameter	10 m
Wing length	10 m
Overspeed control	Safety PLC controller SIL-3 (electrical and hydraulic brake)
Noise	
Value	ca. 40 dB
Wind speed	8 m/s
Distance from pole	30 m
Support	
Pole height	Standard 24 m class III
Weight	
Turbine (without pole)	ca. 3500 kg
Monitoring system	SDMR / SCADA (optional)
Operating temperature	-20°C/+55°C
Operating altitude	≤ 2000 m AMSL

Power curve***

	STANDARD	CUSTOMIZED
Wind Speed (m/s)	*Power* (W)	*Power* (W)
3	61	**61**
4	760	**760**
5	2013	**2013**
6	4038	**4038**
7	6860	**6860**
8	10440	**10440**
9	15039	**15039**
10	20780	**19963**
11	26474	**23504**
11,5	30000	**25000**
12	30000	**27496**
13	30000	**30000**
14	30000	**30000**
15	30000	**30000**
16	30000	**30000**
17	-	**30000**
18	-	**30000**
19	-	**30000**
20	-	**30000**
21	-	**30000**
22	-	**30000**
23	-	**30000**
24	-	**30000**
25	-	**30000**

The turbine can be additionally calibrated according to the site.

AEP *
Distribution K = 2
IEC 61400-12-1

Annual average wind	STANDARD kWh/year	CUSTOMIZED kWh/year
7 m/s	**81000**	**84300**
7,5 m/s	**91700**	**96100**
8 m/s	**102000**	**107400**

As expected, this wind turbine can produce more energy than the previous one, given the fact that it has more nominal power. Same case as previous, as we can see from the power curve shown in figure 13, the blue line delineates the power curve for the standard T30pro, meanwhile the green area does reference to the power curve for the T30pro customized. The power curve for the T30pro is:

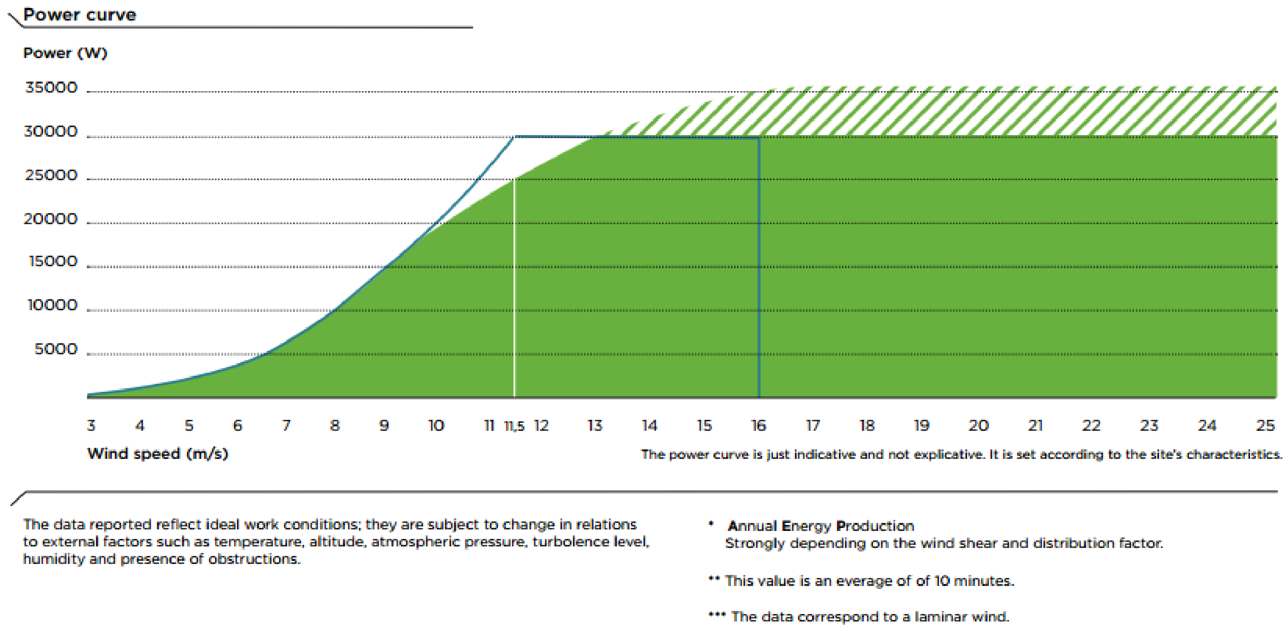


Figure 13. Power curve for T30pro / T30proS.

Deeply into the market, we find **AEOLOS**[10] enterprise.

At Aeolos we can find products in horizontal axis wind turbines from 500w to 50kw and in vertical axis wind turbines from 300w to 10kw. They are widely applied for home, farm, village, school and small wind farm. Aeolos wind generators works in US, Canada, UK, Italy, Spain, Denmark, Germany, France, Netherlands, Australia, Argentina, Russia, Brazil, South Africa, Mozambique and more than 60 countries and regions.

We will make more on this company since for our future analysis it has the greater chance to continue our analysis with it.

First thing to mention is their most used product. They are:

Aeolos-H:
- 500w
- 1000w
- 2000w
- 3000w
- 5000w
- 10kw
- 20kw
- 30kw
- 50kw

Aeolos-V:
- 300w
- 600w
- 1000w
- 3000w
- 5000w
- 10kw

As expected, H is for Horizontal axis turbine, V is for Vertical axis turbine, and the values represent their nominal power.

For our project we would be interested in Aeolos both H-V 5000w, 10kw for cases 2 and 3, and for case 1 the Aeolos-H 20kw, 30kw and 50kw.

Aeolos-H 5000w specifications:

Aeolos-H 5kw wind turbine is the updated design with low RPM generator and PLC control system. It is more reliable and more annual power output than traditional wind turbine with tail. Aeolos-H 5kw wind turbine was protected by the yaw control and electronic brake (dump load) in over wind speed, over voltage and other faults situations. Hydraulic brake is the optional configuration for the strong windy area customers.

Rated Power	5 kw
Maximum Output Power	6 kw
Output Voltage	216V
Blade Quantity	3 Glass Fiber Blades
Rotor Blade Diameter	6.4 m (21 ft)
Start-up Wind Speed	3.0 m/s (6.7 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	45 m/s (100.7 mph)
Generator	Three Phase Permanent Magnetic Generator
Generator Efficiency	>0.96
Turbine Weight	380 kg (836 lbs)
Noise	45 db(A) @ 5m/s
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 2. Characteristics for the AEOLOS-H 5000w.

The rated output voltage is DC 216v for both off grid application and grid tie application. For the off grid application, Aeolos-H 5kw was used not only for house and farms, but also for some small equipments like motors, water pumps.

For the grid tie application, Aeolos-H 5kw wind turbines were usually connected with Power One Aurora 6000w or SMA Wind Boy 6000w inverters. Aeolos hydraulic lift tower is available for the 5kw wind turbine, it will reduce the costs of installation and maintenance.

Aeolos-H 10kw specifications:

Aeolos-H 10kw wind turbine is the updated design with low RPM generator and PLC control system. It is more reliable and more annual power output than traditional wind turbine with tail. Aeolos-H 10kw wind turbine has yaw control, electronic brake and hydraulic brake triple safety protections. Remote monitor and control is the optional configuration for the 10kw wind turbine.

Rated Power	10 kw
Maximum Output Power	13 kw
Generator	Direct-Drive Permanent Magnet Generator
Blade Quantity	3 Glass Fiber Blades
Rotor Blade Diameter	8 m (26.2 ft)
Start-up Wind Speed	3.0 m/s (6.7 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	45 m/s (100.7 mph)
Controller	PLC With Touch Screen
Safety System	Yaw Control, Electrical Brake & Hydraulic Brake
Turbine Weight	420 kg (925.9 lbs)
Noise	45 db(A) @ 5m/s
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 3. Characteristics for the AEOLOS-H 10kw

The 10kw generator output is DC 300v for off grid application and DC 440v for grid tie application. More than one hundred Aeolos-H 10kw wind turbines have been installed in the park, supermarket, farm, island, telecom station and seaside

in the past 10 years. Aeolos 12m and 18m hydraulic lift tower is available for the 10kw wind turbine. This will reduce the costs of installation and maintenance.

Aeolos-H 20kw specifications:

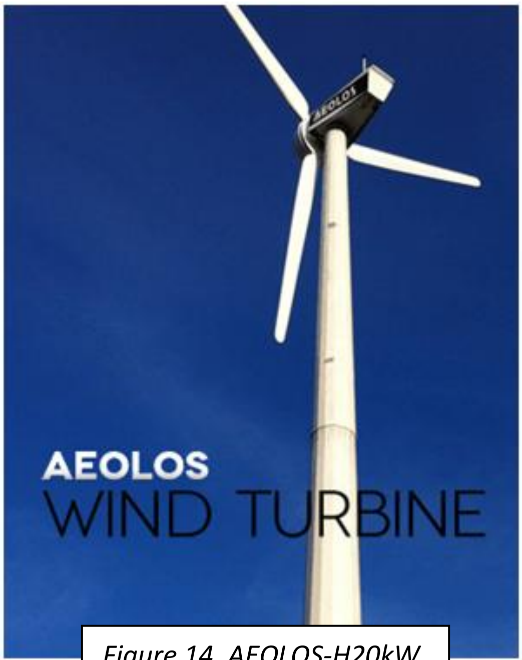


Figure 14. AEOLOS-H20kW.

Aeolos-H 20kw wind turbine is an updated design with three phase direct-drive generator, no gearbox or booster device. It is more reliable and efficient than the induction generator with gearbox or booster. The 20kw wind turbine was controlled by PLC controller with touch screen. There are triple safety protections for Aeolos-H 20kw wind turbine. Remote monitoring and hydraulic lift tower are the optional configurations for the 20kw wind turbine.

20kw off grid wind turbines were usually applied for water pumping system, large farm and village power supply in Pakistan, Brazil, India and Egypt. The grid tie 20kw wind turbine is the popular investment project in the windy source countries, like Italy, Greece, UK, France, Australia, Canada and US.

Rated Power	20 kw
Maximum Output Power	25 kw
Generator	Direct-Drive Permanent Magnet Generator
Blade Quantity	3 Glass Fiber Blades
Rotor Blade Diameter	10.0 m (32.8ft)
Start-up Wind Speed	3.0 m/s (6.7 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	50 m/s (111.5 mph)
Controller	PLC With Touch Screen
Safety System	Yaw Control, Electrical Brake & Hydraulic Brake

Turbine Weight	960 kg (2112 lbs)
Noise	55 db(A) @ 7m/s
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 4. Characteristics for the AEOLOS-H 20kw.

Aeolos-H 30kw specifications:

Rated Power	30 kw
Maximum Output Power	35 kw
Generator	Direct-Drive Permanent Magnet Generator
Blade Quantity	3 Glass Fiber Blades
Rotor Blade Diameter	12.5 m (41.0 ft)
Start-up Wind Speed	3.0 m/s (6.7 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	50 m/s (111.5 mph)
Controller	PLC With Touch Screen
Safety System	Yaw Control, Electrical Brake & Hydraulic Brake
Turbine Weight	1380 kg (3042.3 lbs)
Noise	55 db(A) @ 7m/s
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 5. Characteristics for the AEOLOS-H 30kw.

Aeolos-H 30kw wind turbine used three phase direct-drive generator, no gearbox or booster device. It is more reliable and efficient than the induction generator with gearbox or booster. The 30kw wind turbine is controlled by PLC controller with touch screen. There are triple safety protections for Aeolos-H 30kw wind turbine. Remote monitoring is the optional configuration for the 30kw wind turbine. You can access the wind turbine control panel in anywhere through the internet. Specifications can be seen in table 5.

For the off grid application, Aeolos-H 30kw wind turbines could supply the power to large farm, village, school and small enterprises with battery bank. For the grid on application, it is a good investment project in the rich wind source countries, like Italy, Greece, Spain, UK, France, Australia, German and USA. Aeolos 18m and 24m hydraulic tower is available for the 30kw wind turbine, this will reduce the maintenance cost and fully protect the wind turbine when wind storm is coming.

Aeolos-H 50kW

Aeolos-H 50kw wind turbine used three phase direct-drive generator, no gearbox or booster device. It is more reliable and efficient than the induction generator with gearbox or booster. The 50kw wind turbine is controlled by PLC controller with touch screen. There are triple safety protections for Aeolos-H 50kw wind turbine including yaw control, PWM dump loading system and hydraulic brake system. Remote monitoring is the optional configuration for the 50kw wind turbine. You can access the wind turbine control panel in anywhere through the internet.

Rated Power	50 kw
Maximum Output Power	54 kw
Generator	Direct-Drive Permanent Magnet Generator
Blade Quantity	3 Glass Fiber Blades
Rotor Blade Diameter	18.0 m (59.1 ft)
Start-up Wind Speed	3.0 m/s (6.7 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	50 m/s (111.5 mph)
Controller	PLC With Touch Screen
Safety System	Yaw Control, Electrical Brake & Hydraulic Brake
Turbine Weight	3120 kg (6878.3 lbs)
Noise	58.5 db(A) @ 7m/s
Temperature Range	-20℃ to +50℃

Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 6. Characteristics for the AEOLOS-H 50kw.

Aeolos-V 5000w specifications:

Aeolos 5kw vertical axis wind turbine is a low start wind speed, quiet, safe and reliable vertical wind turbine. We use outer rotor three-phase generator with a 1.5m/s start wind speed. Aeolos vertical axis wind turbines were widely applied for urban, schools, supermarkets, home and low noise area.

The blades were made by aluminum alloy with a special aerodynamic design. This design will limit the max rotating speed to 260rpm even the wind speed is 30m/s or 40m/s. It is more safety and reliable than traditional vertical axis wind turbine.

Rated Power	5kw
Maximum Output Power	6kw
Output Voltage	220 V
Rotor Height	3.6 m (11.8 ft)
Rotor Diameter	3.0 m (9.8 ft)
Start-up Wind Speed	1.5 m/s (3.4mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	50 m/s (111.5 mph)
Generator	Permanent Magnetic Generator
Generator Efficiency	>0.96
Turbine Weight	78 kg (171.6 lbs)
Noise	<45dB(A)
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 7. Characteristics for the AEOLOS-V 5000w.

Aeolos-V 10kw specifications:

Figure 15. AEOLOS-V 10kW.

Aeolos 10kw vertical axis wind turbine is a low start wind speed, quiet, safe and reliable vertical wind turbine. We use outer rotor three-phase generator with a 1.5m/s start wind speed. It can be used for a 300v off grid application or 380v grid tie application. Aeolos 10kw vertical axis wind turbines were widely applied for building, small farm, schools, supermarkets, home and other low noise area.

The blades were made by aluminum alloy with a special aerodynamic design. This design will limit the max rotating speed to 260rpm even the wind speed is 30m/s or 40m/s. It is more safety and reliable than traditional vertical axis wind turbine.

Rated Power	10 kw
Maximum Output Power	12 kw
Output Voltage	300/380 V
Rotor Height	3.6 m (11.8 ft)
Rotor Diameter	3.0 m (9.8 ft)
Start-up Wind Speed	1.5 m/s (3.4 mph)
Rated Wind Speed	10 m/s (22.3 mph)
Survival Wind Speed	50 m/s (111.5 mph)
Generator	Permanent Magnetic Generator
Generator Efficiency	>0.96
Turbine Weight	78 kg (171.6 lbs)

Noise	<45dB(A)
Temperature Range	-20°C to +50°C
Design Lifetime	20 Years
Warranty	Standard 5 Years

Table 8. Characteristics for the AEOLOS-V 10kw.

Note: The power curve for each of the models will be found in Chapter 5 after directly contacting with the company.

Last but not least, **Windspot company** [11]**. Windspot variable pitch system**, unlike other wind turbines, is robust, effective and requires minimal maintenance. It is also silent, due to the painstaking aerodynamic design of its blades and the fact that it operates at low rpm.

Buying a WINDSPOT small wind turbine is not only an investment in a product of quality, efficiency and reliability, but saves a lot of CO2 from being emitted to the atmosphere.

This quantity represents the CO2 that has been saved by not producing energy from fossil fuels and is obtained by multiplying the energy generated annually by the average CO2 emitted by conventional sources.

The approximate quantity of CO2 emitted by each of the different energy sources is the following:

1 kwh produced with: **Emits (kg de CO^2):**	**Emits (kg de CO^2):**
Coal	0.75 kg (approximate value and dependent on the type of coal)
Fuel oil or diesel oil	0.60 kg
"Natural" gas, conventional centre	0.37 kg
"Natural" gas, combined cycle centre	0.26 kg
Nuclear	little, but not negligible (uranium mining, transport, etc)
Hydraulic	despreciable

Wind	despreciable

If there is an extra demand, this extra cannot be generated with either nuclear, wind or hydraulic. Only coal and fuel oil can increase the production at power stations, for which if we save 1Kwh, we will save the equivalent in coal or fuel oil.

For example, with a medium wind of 7 m/s, the different WINDSPOT small wind turbines models would avoid an annual emission of:

WINDSPOT 1.5	3160 kg de CO^2
WINDSPOT 3.5	7400 kg de CO^2
WINDSPOT 7.5	15800 kg de CO^2
WINDSPOT 15	31600 kg de CO

The most basic product of this company is the **WINDSPOT 1.5KW**, which gives a maximum power of 1.5 kW.

In figure 16 we can see its annual production and its power curve.

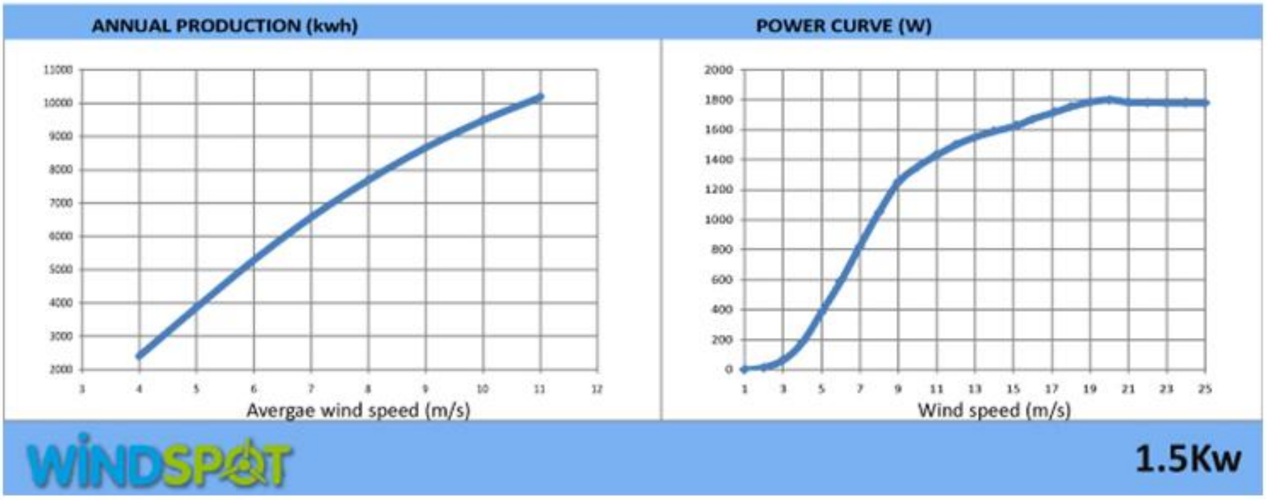


Figure 16. Annual production and Power Curve for the WINDSPORT 1.5KW.

As expected, this wind turbine doesn't cover the power needs for our project. Neither does the 3.5kW one.

Therefore the solution for this company to our project would be the **WINDSPOT 7.5** which gives a maximum power of 7.5 kW and can be considered for cases 2 and 3. Here we can find its specifications and its power curve.

POWER	7.5Kw @ 200 rpm
ROTOR DIAMETER	6.3 m (19.3 ft)
CUT IN SPEED	3 m/s (6.7 mph)
RATED SPEED	12 m/s (26.8 mph)
WEIGHT	420 kg (925 lb)
TOTAL LENGTH	4 m (13.1 ft)
ESTIMATED ANNUAL PRODUCTION	11900-24200 Kwh at 5-7 m/s (11.2-15.7 mph)
C02 SAVED	7730-15700 kg (17000-34600 lb)
TYPE	Up-wind horizontal rotor
GENERATOR	Synchronous, permanent magnets; 3 phases; 48-110-220 V at 50/60 Hz
YAW CONTROL	Passive system: Tail
POWER CONTROL	Passive Centrifugal Variable Pitch System with Shock Absorber (Patented design)
TRANSMISSION	Direct
BRAKE	Electric
CONTROLLER	On-grid, off-grid, water pumping or hybrid system
BLADES	Polyester resin reinforced with Fiber glass
INVERTER	Efficiency ≈ 95% ; Algorithm MPPT
NOISE	37 dB(A) from 60 m with a wind speed of 8 m/s (65 yd and 18 mph)
ANTICORROSION PROTECTION	Sealed design + e-coat + anodizing + UV resistant paint
TOWER	12, 14 and 18 m (39, 46 and 59 ft); hydraulic and mechanical lay down system
DESIGN	According to IEC61400-2

With its respective power curve shown in figure 17. This, we repeat, is the key for the further economical analysis.

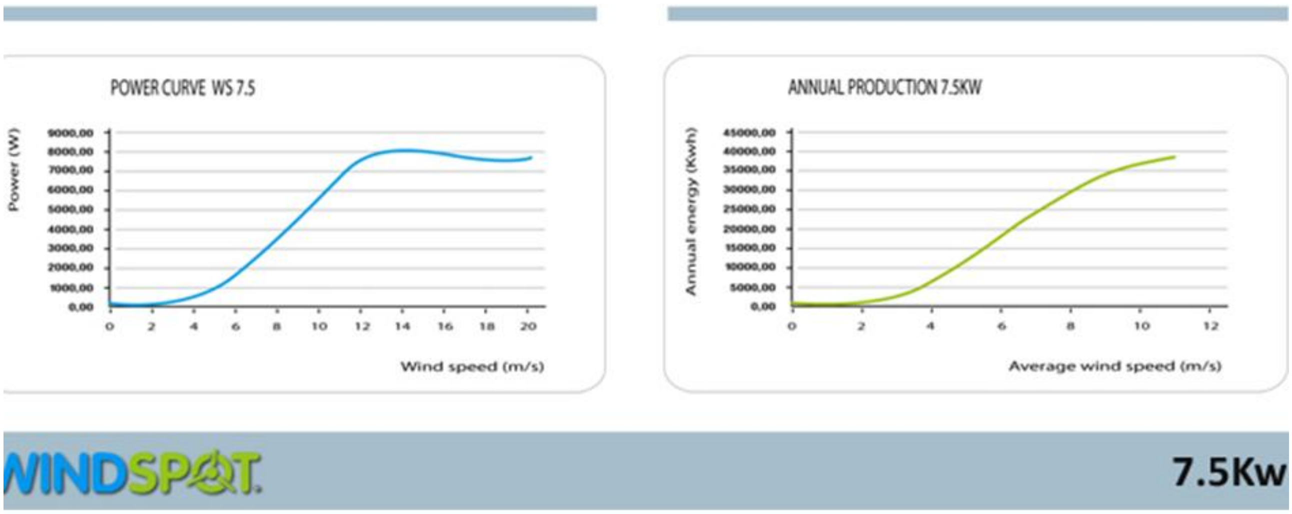


Figure 17. Power curve and Annual production for the WINDSPOT 7.5KW.

CHAPTER 4: ENERGY STORAGE

One of the key aspects for this project is the energy storage.

For nobody is a secret that renewable energies are very irregular, specially sun and wind. Therefore, when production exceeds demand we need to store the extra energy, in order to use it when demand exceeds production.

In particular geographic regions, peak wind speeds may not coincide with peak demand for electrical power. In the US states of California and Texas, for example, hot days in summer may have low wind speed and high electrical demand due to air conditioning.

Energy storage can also be considered the holy grail of renewable power because it would allow wind farms to provide constant energy to the electric grid [12].

Britain just connected its first large-scale battery, rated at 2 megawatts, to the grid in August, in the Orkney Islands. The system resembles several cargo containers and can store more than 10,000 times as much energy as an iPad battery. In Texas, the utility company Duke Energy recently began using an even more powerful battery, rated at 36 megawatts, at a remote wind farm.

Other stranger-sounding ways to store energy are starting to become reality nowadays. For example, compressed air can be stored in places like caverns during times of excess electricity production and it can be released to create power when it is needed, via turbines. Projects using this technology are moving forward in New Hampshire and Germany.

The most widely used energy storage method today on power grids involves huge hydropower systems, in which water gets pumped uphill with extra electricity and then released through turbines when the energy is needed. Such projects are hard to build because they are so large. A new system of this kind is under consideration in Wales.

Dr. Sadoway, founder of the German Energy Storage Association, and his team invented a liquid metal battery, which sandwiches molten salt between two common molten metals that serve as electrodes. He hopes to have an industrial prototype for places where high prices for diesel-generated electricity make renewable energy attractive like Alaska or the Caribbean Islands.

Stored energy increases the economic value of wind energy since it can be shifted to displace higher cost generation during peak demand periods. The potential revenue from this arbitrage can offset the cost and losses of storage; the cost of storage may add 25% to the cost of any wind energy stored, but it is not envisaged that this would apply to a large proportion of wind energy generated.

Energy storage is accomplished by devices or physical media that store energy to perform useful operation at a later time. A device that stores energy is sometimes called an accumulator.

All forms of energy are either potential energy (e.g. Chemical, gravitational, electrical energy, temperature differential, latent heat, etc.) or kinetic energy(e.g. momentum). Some technologies provide only short-term energy storage, and others can be very long-term such as power to gas using hydrogen or methane and the storage of heat or cold between opposing seasons in deep aquifers or bedrock. A battery stores readily convertible chemical energy to operate a mobile phone. Ice storage tanks store ice (thermal energy in the form of latent heat) at night to meet peak demand for cooling. Fossil fuels such as coal and gasoline store ancient energy derived from sunlight by organisms that later died, became buried and over time were then converted into these fuels. Even food (which is made by the same process as fossil fuels) is a form of energy stored in chemical form.

4.1 Electricity Storage

In a beginning, when batteries started to appear in the market and working to be an electrochemical storage device, they tended to be a very high cost devices. Not only their price was very high, but also their storage capacity was relatively small. Nevertheless they started to gain strength, and so, since about the middle of the first decade of the 21st century, newer battery technologies have been developed [13].

A similar possible solution to deal with the intermittency issue of solar and wind energy is found in the capacitor.

We will now proceed to talk about some different storage methods for electricity, mentioning among them simple ones as batteries and some more difficult to build or perform such as pumping water to high altitudes in order to let them pass later through turbines, or decomposing H_2O to obtain H_2 for further releasing of energy.

4.1.1 Grid energy storage

This is the most accurate option that we will take into account when realizing the analysis for our project. Not only it offers a simple solution to our eolic installation, but also in Italy this storage system is well developed.

Grid energy storage (or large-scale energy storage) as we mentioned before, lets energy producers send excess electricity over the electricity transmission grid to temporary electricity storage sites that subsequently become energy suppliers when electricity demand is greater. Grid energy storage is particularly important in matching supply and demand over a 24 hour period of time.

In chapter 6 we will talk more about this system.

4.1.2 Hydrogen

As we mentioned before, hydrogen is also being developed as an electrical power storage medium. Hydrogen is not a primary energy source, but a portable energy storage method. It must first be manufactured by other energy sources in order to be used. However, as a storage medium, it may be a significant factor in using renewable energies.

With intermittent renewable energies such as solar and wind, the output may be fed directly into an electricity grid. At penetrations[1] below 20% of the grid demand, this does not severely change the economics; but beyond about 20% of the total demand external storage will become important. If these sources are used for electricity to make hydrogen, then they can be utilized fully whenever they are available, opportunistically.

4.1.3 Power to gas

Power to gas is a technology which converts electrical power to a gas fuel. There are 2 methods, the first is to use the electricity for water splitting by means of electrolysis and inject the resulting hydrogen into the natural gas grid. The second method is to combine the hydrogen with carbon dioxide and convert the two gases to methane, using electrolysis and a methanation reaction such as the Sabatier reaction or biological methanation. The excess power or off peak power generated by wind generators or solar arrays is then used for load balancing in the energy grid.

4.1.4 Capacitors

Capacitors store electricity in an electric charge. Capacitors have among the fastest response time of any energy storage device, and are typically used in power quality applications such as providing transient voltage stability. However, their low energy capacity has restricted their use in longer time-duration applications. A major research goal is to increase their energy density and increase their usefulness in the grid (and potentially in vehicle applications.)

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[1]**Penetration**: Wind energy "penetration" refers to the fraction of energy produced by wind compared with the total available generation capacity.

At present, a few grid systems have penetration of wind energy above 5%: Denmark (values over 19%), Spain and Portugal (values over 11%), Germany and the Republic of Ireland (values over 6%). The Danish grid is heavily interconnected to the European electrical grid, and it has solved grid management problems by exporting almost half of its wind power to Norway. The correlation between electricity export and wind power production is very strong.

Intermittency and penetration limits: Electricity generated from wind power can be highly variable at several different timescales: from hour to hour, daily, and seasonally. Annual variation also exists, but is not as significant. Related to variability is the short-term (hourly or daily) predictability of wind plant output. Like other electricity sources, wind energy must be "scheduled". Wind power forecasting methods are used, but predictability of wind plant output remains low for short-term operation.

Because instantaneous electrical generation and consumption must remain in balance to maintain grid stability, this variability can present substantial challenges to incorporating large amounts of wind power into a grid system. Intermittency and the non-dispatchable nature of wind energy production can raise costs for regulation, incremental operating reserve, and (at high penetration levels) could require an increase in the already existing energy demand management, load shedding, or storage solutions or system interconnection with HVDC cables. At low levels of wind penetration, fluctuations in load and allowance for failure of large generating units requires reserve capacity that can also regulate for variability of wind generation. Wind power can be replaced by other power stations during low wind periods.

4.1.5 Superconducting Magnetic Energy Storage (SMES)

SMES stores energy in a magnetic field in a coil of superconducting material. SMES is similar to capacitors in its ability to respond extremely fast, but it is limited by the total energy capacity. This has also restricted SMES to “power” applications with extremely short discharge times.

4.1.6 Mechanical storage

Energy can be stored in water pumped to a higher elevation using pumped storage methods, by moving solid matter to a higher location, by compressing air, or by storing it in spinning flywheels.

A mass of 1 kg, elevated to a height of 1,000 m stores 9.8 kJ of gravitational energy, which is equivalent to 1 kg mass accelerated to 140 m/s.

4.1.6.1 Pumped Hydro Storage (PHS)

Pumped hydro is the only energy storage technology deployed on a gigawatt scale in the United States and worldwide. In the United States, about 20 GW is deployed at 39 sites, and installations range in capacity from less than 50 MW to 2,100 MW.77 Many of the sites store 10 hours or more, making the technology useful for load leveling. PHS is also used for ancillary services. PHS uses conventional pumps and turbines and requires a significant amount of land and water for the upper and lower reservoirs. PHS plants can achieve round-trip efficiencies that exceed 75% and may have capacities that exceed 20 hours of discharge capacity.

4.1.6.2 Compressed air energy storage (CAES)

Compressed air energy storage technology stores low cost off-peak energy, in the form of compressed air in an underground reservoir/cavity. CAES uses the elastic potential energy of compressed air. The air is released during peak load hours and heated with the exhaust heat of a standard combustion turbine. When electricity is needed, this heated air is converted to energy through expansion turbines to produce it.

4.1.6.3 Flywheels [16]

Figure 18. Flywheel system.

Flywheels store energy in a rotating mass. Flywheels feature rapid response and high efficiency, making them well-suited for frequency regulation.

Flywheel energy storage works by accelerating a cylindrical assembly called a rotor (flywheel) to a very high speed and maintaining the energy in the system as rotational energy. The energy is converted back by slowing down the flywheel. The flywheel system itself is a ´kinetic, or mechanical battery, spinning at very high speeds to store energy that is instantly available when needed.

When charging (or absorbing) energy, the flywheel's motor acts like a load and draws power from the grid to accelerate the rotor to a higher speed. When discharging, the motor is switched into generator mode, and the inertial energy of the rotor drives the generator which, in turn, creates electricity that is then injected back into the grid. Multiple flywheels may be connected together to provide various megawatt-level power capacities. Performance is measured in energy units - kilowatt-hours (kWh) or megawatt-hours (MwH), indicating the amount of power available over a given period of time.

Beacon company is a manufacturer of this type of technology. Beacon's Smart Energy 25 flywheel has a high-performance rotor assembly that is sealed in a vacuum chamber and spins between 8,000 and 16,000 rpm. At 16,000 rpm the flywheel can store and deliver 25 kWh of extractable energy. At 16,000 rpm, the surface speed of the rim would be approximately Mach 2 - or about 1500 mph - if it were operated in normal atmosphere. At that speed the rim must be enclosed in a high vacuum to reduce friction and energy losses. To reduce losses even further, the rotor is levitated with a combination of permanent magnets and an electromagnetic bearing.

Sustainability:

Flywheel-based energy storage systems, unlike fossil-fuel power plants that are used on the grid for frequency regulation, are sustainable "green" technology solutions that consume no fossil fuel, nor produce CO_2 or other emissions during operation. Further, Beacon's flywheels operate reliably for many years with little or no maintenance, making them a true sustainable technology solution.

4.1.7 Several battery technologies, which include ead-acid, nickel-cadmium, nickel-metal hydride, and (more recently) lithium-ion have arapid response, and they can provide power quality services such as frequency regulation; but the continuous cycling requirement can limit battery life.

The most mature high-temperature battery as of 2009 is the sodium-sulfur battery, which has worldwide installations that exceed 270 MW. The second class of high-energy batteries is the liquid electrolyte “flow” battery. This battery uses a liquid electrolyte that flows across a membrane.

4.1.8 Batteries

When talking about batteries we definitely are talking about a very wide sector nowadays. Many types of batteries can be found in the market with very different features one and another as we can see in point 4.5, trying each one of them to reach the best efficiency with the minimum cost possible.

An electric battery is a device consisting of one or more electrochemical cells that convert stored chemical energy into electrical energy. Each cell contains a positive terminal, or cathode, and a negative terminal, or anode. Electrolytes allow ions to move between the electrodes and terminals, which allows current to flow out of the battery to perform work.

We will now mention some of the most relevant features found in the market, and later, after defining the characteristics we need for our project, we will see the diversity found in the market.

Figure 19. Camco Clean Energy storage system.

Camco Clean Energy led consortium develops renewable energy storage technology [17]

Camco Clean Energy has led a consortium in a collaborative project that successfully designed, developed, constructed and tested a prototype 5 kW renewable energy storage system based on vanadium redox flow battery (VRFB) technology. For many applications, conventional lead-acid batteries are used, but they are an expensive and inefficient option because of performance limitations and the need for frequent replacement. The principal advantage of VFRB is that, unlike conventional batteries, it separates the power delivery module (known as the stack) from the energy storage medium (electrolyte) and can be charged as quickly as it was discharged. Energy can be stored for days and returned to the grid when required. The VRFB also has a pivotal position in terms of the development of the ‘smart grid’ as it enables simultaneous management of multiple generation sources.

ZBB enterprise. [18]

ZBB enterprise has batteries that can cover power needed from 50 kWh to 2MWh. This energy storage system works with the chemical reaction of Zinc and Bromine showed in figure 20.

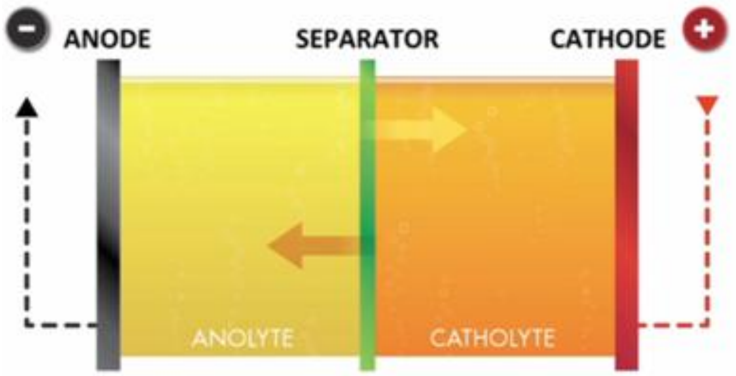

Figure 20. Chemical process for the ZBB batteries.

ZBB enterprise, as we can see in figure 21, proposes an energy transmission and distribution with a control center that manages all the fluxes of energy, monitoring the production, consumption and storage of energy, as well as controlling the operations with the grid if present.

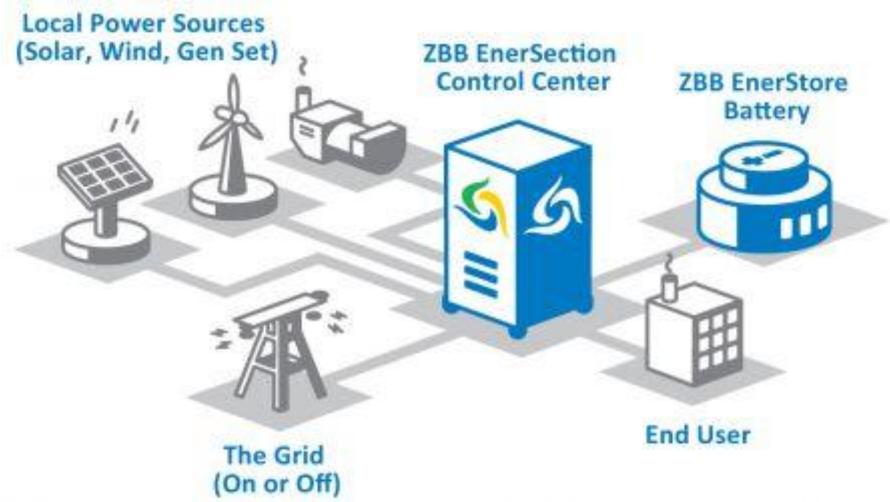

Figure 21. Chemical process for the ZBB batteries.

While high performance batteries today can cost between $700 and $800 per kilowatt hour (kWh), and lower performance batteries cost between $400 and $500/kWh, prices are headed downward drastically for those battery companies that survive.

Among of the most important facts in energy storage, ZBB Energy Corp. considerates that the development of microgrids[2] is the single greatest factor that will drive the energy storage industry. Microgrids as a Natural Energy Storage Host.

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[2] The interconnection of small, modular generation sources to low voltage distribution systems can form a new type of power system, the MicroGrid. MicroGrids can be connected to the main power network or be operated autonomously, if they are isolated from the power grid, in a similar manner to the power systems of physical islands. The objectives of the proposal are:

- To increase the penetration of RES and other micro-sources in order to contribute for the reduction of GHG emissions.
- To study the main issues regarding the operation of MicroGrids in parallel with the mains and in islanding conditions that may follow faults;
- To define, develop and demonstrate control strategies that will ensure the most efficient, reliable and economic operation and management of MicroGrids;
- To define appropriate protection and grounding policies that will assure safety of operation and capability of fault detection, isolation and islanded operation;
- To identify the needs and develop the telecommunication infrastructures and communication protocols required
- To determine the economic benefits of the MicroGrid operation and to propose systematic methods and tools to quantify these benefits and to propose appropriate regulatory measures

Reducing Battery Price, also Key to Growth

One innovative battery maker, Ionex Advanced Energy Storage Systems, of Long Beach, is developing a battery based on a silicon and graphene anode, that will discharge “faster than any other battery on the market,” says Phillip Roberts, the company CEO, also spoke at the symposium. Utilizing technology originally developed at Argonne National Laboratory, Ionex is currently working with global battery manufacturers, targeting a price of $350 per kilowatt hour for its batteries. “We hope to get down to $150/kwh over the next 18 months or two years, with a 5,000-cycle lifetime,” he says.

Improving

Valerio De Angelis, the vice president of grid storage systems at Urban Electric Power, supports that their power battery can discharge 85 percent in 30 minutes, or 100 percent over 4 hours; the life of the battery is 10 years, compared with a lead acid battery that would fail after 250 cycles or so.

“Our building consumes 1 MW, and by chopping 15 minutes of peak use time, we can amortize the cost of our energy storage system in three years,” De Angelis says.

Urban Electric Power also has developed a Zn-MnO2 energy battery that can be used for industrial applications where the use peak is flatter than commercial use spikes,” De Angelis says. “This battery is available for $70/kwh but the operating cost works out to a few cents per kW cycle — that’s cheaper than you can buy a car battery,” he says.

There are also some other types of storage rather than electrical ones. We won't use them for the develop of our thesis, but we will still just mention them very quickly as information complementary facts.

4.2 Short-term thermal storage, as heat or cold [14]

In the 1980s, a number of manufacturers carefully researched thermal energy storage (TES) to meet the growing demand for air conditioning during peak hours. Today, several companies manufacture TES systems. The most popular form of thermal energy storage for cooling is ice storage, since it can store more energy in less space than water storage and it is also less costly than energy recovered via fuel cells or flywheels. Thermal storage works by creating ice at night when electricity is usually less costly, and then using the ice to cool the air in buildings during the hotter daytime periods.

Latent heat can also be stored in technical phase change materials (PCMs), besides ice.

When used for the proper application with the appropriate design, off-peak cooling systems can lower energy costs.

The advantages of thermal storage are:

- Commercial electrical rates are lower at night;
- it takes less energy to make ice when the ambient temperature is cool at night. Source energy (energy from the power plant) is saved.
- a smaller, less costly system can do the job of a much larger unit by running for more hours.

4.3 Interseasonal thermal storage, as heat or cold [15]

Another class of thermal storage that has been developed since the 1970s that is now frequently employed is seasonal thermal energy storage (STES). It allows heat or cold to be used even months after it was collected from waste energy or natural sources, even in an opposing season. The thermal storage may be accomplished in contained aquifers, clusters of boreholes in geological substrates as diverse as sand or crystalline bedrock, in lined pits filled with gravel and water, or water-filled mines. An example is Alberta, Canada's Drake Landing Solar Community, for which 97% of the year-round heat is provided by solar-thermal collectors on the garage roofs, with a borehole thermal energy store (BTES) being the enabling technology. STES projects often have paybacks in the 4-6 year range.

4.4 So now... What do we need for our application?

For economical and practical reasons, we choose to use batteries for our project. Due to the relatively low power needed (barely reaches 5kW), other methods will be discarded.

A basic knowledge of how battery works is explained by General Electric [19]. For that, they explain their Durathon Battery model. Durathon Battery technology is based on the simple chemistry of sodium and nickel. During charging, chloride ions are released from sodium chloride and combined with nickel to form nickel chloride. These sodium ions then migrate from the cathode reservoir through a beta alumina separator into the anode reservoir. During discharge, the reverse chemical reaction occurs and sodium ions migrate from the anode reservoir through the beta alumina separator into the cathode reservoir. There is no self-discharge because sodium ions can move easily across the beta alumina, while electrons cannot.

Each cell is hermetically sealed within its own metal case, and is strung together with other cells in a thermally insulated battery module, which ensures that the battery's external surfaces remain within 10°C to 15°C of the surrounding ambient temperature.

This sodium nickel technology provides value and ingenuity to fields such as Telecommunications, Power Generation, Grid Operation and Energy Management.

Also in the system we can find the regulator into the batteries, which controls the electric generation from the solar panels, the aerogenerators, and the condition of the batteries, preventing them from exceed charging and discharging.

Finally the inverter, which transforms the electricity stored in continous current (CC) into altern current (AC) to 220V ready for consumption.

Our project needs

In order to make an analysis and value the importance of an energy storage system in our project it is very important to define in some way the energy needed for our application. Therefore, we make an hypothesis for the project with a lack of wind/sun for 3 days. At a developing stage we need to feed an electrical load of 4.7kW, approximately 5 kW, for 3 days (72 hours) in summer (in winter some free cooling might be used). We need to search then for a battery/system capable of giving 360kWh with a Power of 5kW.

To select the right batteries it's important to analyze and define some basic parameters that define their accumulation capacity. These are [20]:

Capacity in Ah: it's the quantity of discharging current that the accumulator is capable of providing in a certain amount of time (at a fixed temperature). This depends on factors such as: discharging regime, temperature, electrolyte composition.

Capacity in Wh: it's the integral of the product voltage current at the terminals of the accumulator of the battery voltage completely charged until reaching the cut-off voltage.

Open circuit voltage (Voc): it's the voltage that the accumulator has when any load is applied to it. This is, the vacuum voltage in a certain instant. This voltage decreases linearly with the decreasing of the state of charge (SOC).

Cut circuit current (Icc): it's the maximum current that we can obtain when short-circuiting the battery. This depends on the internal resistance.

Internal resistance (Ri): it's the resistance that induces the voltage drop when a load current cuts across the battery.

State of charge (SOC): it's the quantity of energy that, in a certain period, a battery has. It can be also defined as the relation between the current amount of energy that the battery has and the maximum that it can store. In some cases the DOD (Depth of discharge) is defined. This is SOC = 100 – DOD.

Self discharge coefficient: It's the fraction of the charging content that the battery looses spontaneously in the time unit. This coefficient takes a typical value between 0.5 and 1% a day.

Capacity of the battery (Qb): it warranties a certain numbers of days (Nga) of autonomy for the battery. We can define this value as

$$Qb = \frac{E_{cmax} \cdot N_{ga}}{\eta_b \cdot DOD}$$

where η_b is the performance of charging and discharging of the battery (usually takes a value of 80%). N_{ga}, as we mentioned before, number of days of autonomy for the battery. E_{cmax} the maximum average value of daily energy a month needed for the load. DOD usually takes a value of 80%.

Having said this, the capacity we obtain for our project battery would be:

$$Qb = \frac{5kW \cdot 24h \cdot 3}{0.8 \cdot 0.8} = 562.5kWh$$

value for which choosing a standard 12V battery turns out to be

$$\frac{562.5kWh}{12V} = 46875Ah$$

Another method for the dimensioning is applying the following formula, always using the same numerator for the power but changing the denominator,

$$Qb = \frac{E_{cmax} \cdot N_{ga}}{\eta_b \cdot V_n \cdot k_f}$$

where V_n is the nominal voltage of the battery and k_f a correction factor that depends on the number of days of autonomy in the following way

N_{ga}	2	3	4	5	6
k_f	1.37	1.43	1.49	1.5	1.51

The result of this method is:

$$Qb = \frac{5kW \cdot 24h \cdot 3}{0.08 \cdot 12V \cdot 1.43} = 26224Ah$$

This obtained value is lower than the one obtained in the previous method, therefore we keep with the most unfavorable case, which is a pre-dimensioning of 46875Ah.

Therefore we could use x's units of batteries of x's Ah to meet 46875Ah.

Now let's take a look at the market to see what many companies offer in order to check out the most doable choice for our project.

4.5 Some Battery Manufacturers

After analyzing the amount of energy we will need for the battery it's time to analyze what's on the market.

Companies like Bornay,[3] has an extended gamma selection for batteries. Among them we can find:

Monobloc DEKA batteries:

Model	Information	Voltage (V)	Ah C20	Ah C5	Discharging time		
					75 Amp	25 Amp	23 Amp
GC15	4, 11, 36, U	6	230	179	120	448	-
8C6V	4, 11, 17, 19, 25, 35, V	6	330	270	170	-	-
8L16	4, 11, 17, 19, 25, 34, W	6	370	295	190	-	-
DC24	11, 17, 35, U	12	75	-	-	130	150
DC27	11, 17, 35, U	12	90	-	-	175	200
DC31DT	11, 17, 21, 22, 35, U	12	105	-	-	185	225
GC12V	7, 11, O	12	155	-	77	110	292
9C12	11, 17, 25, 34, V	12	228	180	115	-	-

It would be necessary around 200 units of the 9C12 (12V, 228Ah).

Monobloc AGM/Gel:

AGM

Modelo	Voltage (V)	CapacityC20 25°C Ah
BAT406225080	6	240
BAT412550080	12	60
BAT412600080	12	66
BAT412800080	12	90
BAT412101080	12	110
BAT412121080	12	130
BAT412151080	12	165
BAT412201080	12	220

GEL

Model	Voltage (V)	Capacity C20 25°C Ah
BAT412550100	12	60
BAT412600100	12	66
BAT412800100	12	90
BAT412101100	12	110
BAT412121100	12	130
BAT412151100	12	165
BAT412201100	12	220

Around 210 units of the BAT412201080 (12V, 220Ah) or BAT412201100 (12V, 220Ah) would cover the needs for our project..

BAE Secura Block Solar:

Operative information

· Depth of discharge - Max. 80 % (Ue = 1.91 V/elto for charging periods of >10 h; 1.80 V/elto for 1 h)

· Deep discharges of over 80 % should be avoided.

· Charging current - May vary from 5 x I10 reducing to 0,01 x I10.

· Charged voltage of cyclic operation - Not allowed from 2.30 V to 2.40 V.

· Flotation voltage - 2.23 V/element

· Cicles - 2700 (A+B) cicles IEC 61427.

· Temperature: -20 °C to 55 °C, recommended from 10 °C to 30 °C.

· Self discharge - Aprox. 3 % per month to 20 °C.

Model	Cap. Nominal C100 1,80 V/C Ah	Nominal Cap. C120 1,80 V/C Ah	l	Internal Res. mohm	Short circuit current A
12V 1PVS70	71	72	272	16,62	0,75
12V 2PVS140	140	140	272	8,91	1,40
12V 3PVS210	215	217	380	6,27	1,99
6V 4PVS280	287	289	272	2,47	2,52
6V 5PVS350	359	361	380	2,09	2,98
6V 6PVS420	431	434	380	1,82	3,42

For them, it would be necessary around 215 units of the 12V 3PVS210 (12V, 217 Ah) or 6V 6PVS420 (6V, 434Ah).

BAE Secura PVS Solar:

Operative information: Same as BAE Secura Block Solar but

· Depth of discharge - Max. 80 % (Ue = 1.91 V/elto for charging periods of >10 h; 1.74 V/elto for 1 h)

· Charging current - Unlimited, minimum current should be of I10.

· Cicles - 3150 (A+B) cicles IEC 61427.

Model	Nominal Cap. C100 1,80 V/C Ah	l	Internal Res. mohm	Short circuit current A	Poles
2 PVS 140	143	105	1,52	1,37	1
2 PVS 210	215	105	1,06	1,96	1
4 PVS 280	287	105	0,84	2,46	1
5 PVS 350	359	126	0,70	2,98	1
6 PVS 420	431	147	0,60	3,47	1
5 PVS 550	496	126	0,57	3,61	1
6 PVS 660	595	147	0,49	4,18	1
7 PVS 770	694	168	0,44	4,69	1
6 PVS 900	877	147	0,47	4,41	1

7 PVS 1050	1020	215	0,36	5,66	2
8 PVS 1200	1160	215	0,32	6,36	2
9 PVS 1350	1300	215	0,33	6,20	2
10 PVS 1500	1450	215	0,28	7,25	2
11 PVS 1650	1590	215	0,28	7,36	2
12 PVS 1800	1740	215	0,24	8,41	2
11 PVS 2090	1870	215	0,24	8,38	2
12 PVS 2280	2040	215	0,22	9,48	2
13 PVS 2470	2210	215	0,16	13,03	3
14 PVS 2660	2380	215	0,15	13,82	3
15 PVS 2850	2550	215	0,14	14,43	3
16 PVS 3040	2710	215	0,13	15,20	3
17 PVS 3230	2910	215	0,12	16,91	4
18 PVS 3420	3108	215	0,11	17,55	4
19 PVS 3610	3276	215	0,11	18,36	4
20 PVS 3800	3444	215	0,11	18,92	4
22 PVS 4180	3780	215	0,10	19,92	4
24 PVS 4560	4128	215	0,09	21,26	4
26 PVS 4940	4464	215	0,09	22,49	4

Or in other case, it would be necessary 63 units of 26 PVS 4940 (2V, 4464Ah).

Samsung's Energy Storage System (Lithium ion batteries) [21]

The efficiency of the power supplied by renewable energy sources can be maximized when paired with an energy storage system. Efficient renewable energy storage offered by Samsung SDI's ESS (Energy Storage System) can store a large amount of power from a renewable energy source when it is sunny or windy; the energy is stored in the energy storage system and is available for later use during cloudy or windless conditions.

ESS Storage System Application

Energy storage system applications are classified according to power, energy capacity, usage time, etc. Applications include megawatt-scale power storage for frequency regulations, large capacity energy storage (MWh scale) for peak time demand response, and residential energy storage with medium capacity (kWh scale).

ESS Products

RES/CES

Residential Energy Storage Systems are connected with small-sized wind turbines or solar modules to charge energy and discharge when needed. The capacity of the RES differs according to the region of its installment, but are mostly designed to be lower than 10kWh. Their main functions are:

- Save electricity bill by charging when the rates are low and discharging when the rates are high.

- Synchronize energy consumption pattern of households and solar power generation

- Provide back-up energy in cases of blackouts

- Surplus energy generated from the sun can be stored in the RES and used whenever the need arises

5.8kWh RES (EU)

Figure 22. 5.8KWh RES device.

	Module	5.8kWh RES
Capacity (kWh)	2.9	5.8
Power (kW)	2.9	5.8
Dimension (mmxmmxmm)	[]	990 x 300 x 627
Weight (kg)	40	150

7.2kWh RES (JP)

Figure 23. 7.2KWh RES device

	Module	7.2kWh RES
Capacity (kWh)	1.2	7.2
Power (kW)	1.2	7.2
Dimension (mmxmmxmm)	333 x 214 x 161	900 x 345 x 1.250
Weight (kg)	16.7	200

In this case, we are talking about 78 units of this battery (7.2kWh RES (JP)).

Base Transceiver Station (BTD)

Figure 24. BTD.

On-grid: Installed in rooftops of buildings in the city and connected to the grid. Mainly installed for the purpose of providing backup energy in cases of power outages.

Off-grid: Installed in connection with diesel generators and solar modules in regions where electricity is unreachable. The capacity of the ESS differs depending on the type of energy generator, but our Tray type design has its flexibility and can match all customer needs.

Product Information

BTD

Figure 25. Models for the BTD

	48V 35Ah	48V 41Ah	48V 21Ah	48V 25Ah	48V 15Ah	48V 17Ah
Capacity (kWh)	35Ah 1.65KWh	41.6Ah 1.95KWh	21Ah 0.99KWh	25Ah 1.17KWh	15Ah 0.70KWh	17.7Ah 0.83KWh
Voltage (V)	41~52V		41~52V		41~52V	
Dimension (mm x mm x mm)	440 x 470 x 84		350 x 375 x 84		240 x 475 x 85	
Weight (kg)	23		16		10.5	

With this option we would need approximately 288 units of the 48V 41Ah batteries.

Currently the biggest competing technology is lead-acid. However, with the adoption of Samsung SDI's lithium based batteries for BTS, it has its advantages in saving space, lighter weight, longer replacement intervals and quick charge capabilities.

Features	VRLA (48V/600Ah)		LIB (48V/273Ah)
Space required	$0.486m^3$	Save more than half	$0.227m^3$
Weight	900 kg	5~7 times lighter	150 kg
Cycle Life @ 25°C	App. 300 cycle	10 times longer life	App. 3,500 cycle
Replacement	2~4 years		10 years
Charging Time	10~12 hours	Quick Charge	2~5 hours

With this type of batteries, 20 units of the VRLA (48V/600Ah) or 43 units of LIB (48V/273Ah) would be needed.

<u>Internet Data Center (IDC)</u>

Figure 26. Internet Data Center.

Internet Data Centers need a steady flow of energy. A sudden power outage can lead to detrimental financial losses. As a safety measure UPS' are installed in IDCs, which are currently backed up by lead-acid batteries. However, lithium batteries are more superior in its long lifespan and low maintenance cost, which will be brought to light in the near future.

The most important role of UPS is in its seamless stream of energy. UPS serves the role of providing energy when there is a momentary cut of energy due to natural disasters and server failures.

Currently, Samsung SDI replaced lead-acid with LIB in Shinhan Bank for the first time in the world and also to an IT solution provider, Duzon.

Product Information

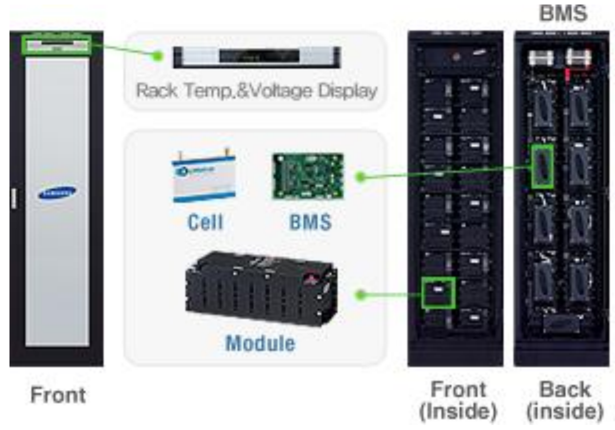


Figure 27. Internet Data Center.

	Module	5.8kWh RES
Capacity (kWh)	1.8	32.0
Power (kW)	1.8	32.0
Dimension (mmxmmxmm)	180 x 437 x 155	600 x 700 x 2,000
Weight (kg)	22	520

- Samsung SDI' s UPS is equipped with its in house BMS. Monitoring of the batteries is maximized through the installment of displays on the products.

Approximately 97 units of these batteries would be needed.

<u>Industrial Products</u>

Figure 28. Industrial storing device.

	Rack	Container ESS
Capacity (kWh)	56.8	1MWh
Power (kW)	56.8	1MW
Dimension (mmxmmxmm)	1,084 x 600 x 1,763	45ft. Container
Weight (kg)	1,250	520

This option could satisfy our demand even without the double days hypothesized without wind (6 days).

Some of the projects presented by Samsung are:

Jeju MW scale Project

– Development of MW scale Lithium-ion battery system in connection with renewable energy

– Samsung SDI developed optimal large scale LIB battery system

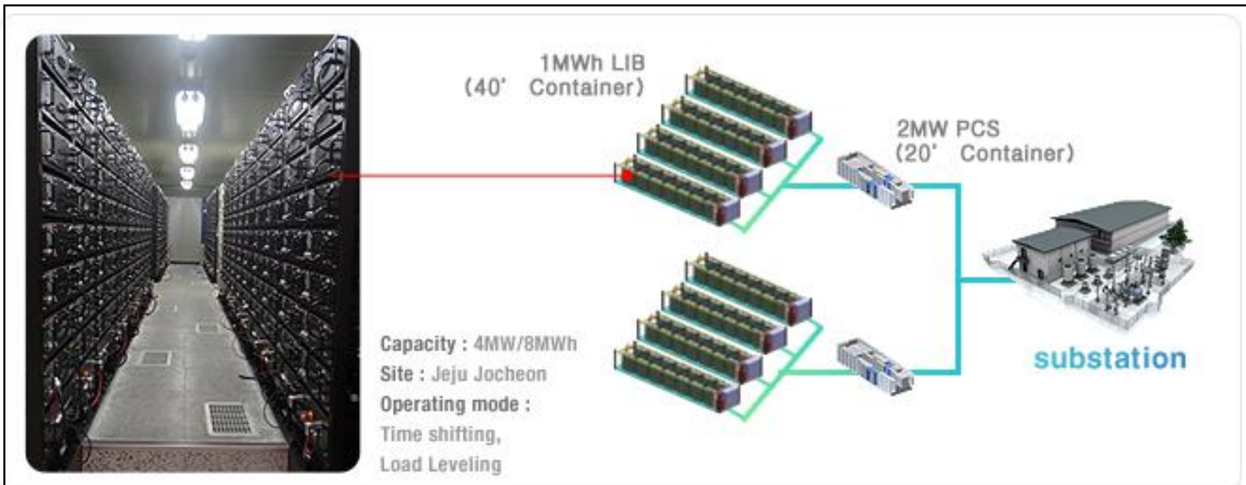


Figure 29. Jeju MW scale project of 1MWh capacity

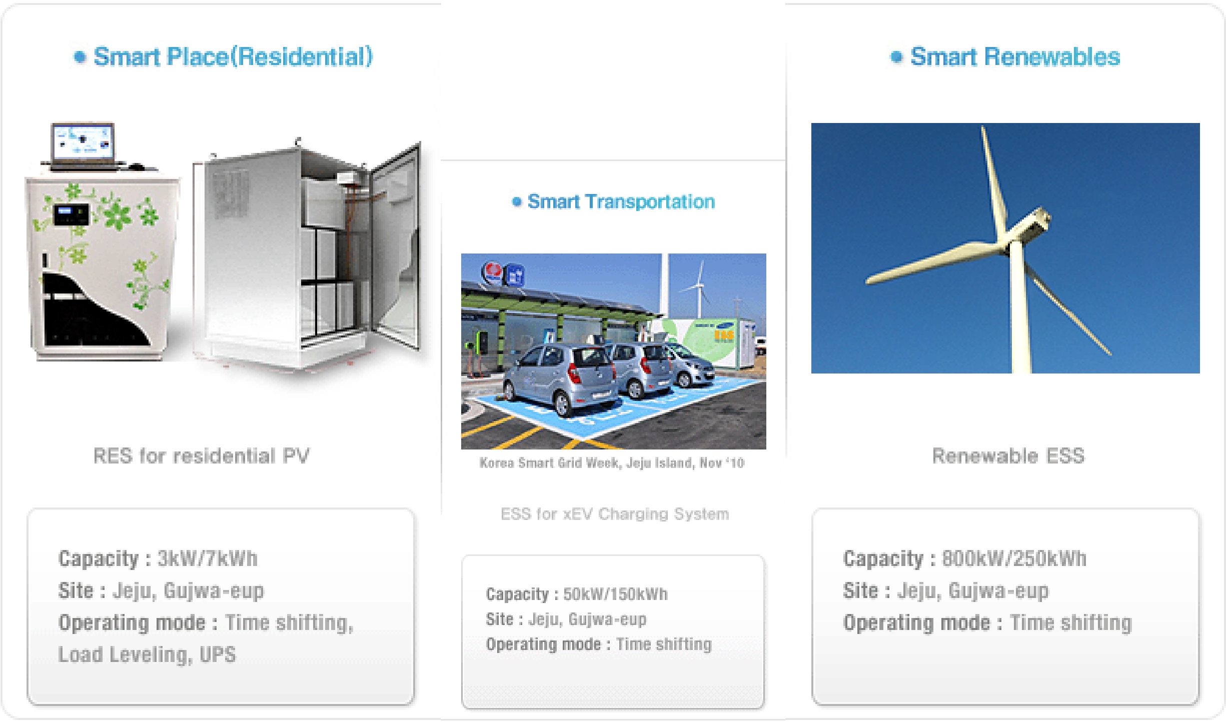


Figure 30. Other projects for Samsung

Some installations already built (○ *Installation complete)*

	Photo	Location	Start Operation	Application	Capacity
○		Korea, Jeju	June 2011	Wind	800kW/200kWh
○				RES	10kW/7kWh 52EA
○		Korea, Daegu	April 2012	RES	3kW/10kWh 100EA
○		Korea, Daejeon	November 2012	Micro Grid	50kW/50kWh
○		Korea, Jeju	June 2011	Community	20kW/20kWh 6EA
○		Spain, Soria	May2012	Wind	50kW/50kWh
○		Malaysia	February 2012	UPS	500kVA/200kWh 2EA
○		Korea. Chuncheon	October 2011	UPS	300kVA/125kWh
○		Italy	May 2012	Peak Shift	50kW/50kWh 5EA
○			June 2012	Community	32kW/32kWh
○		Canada	June 2012	Micro Grid	25kW/75kWh
○		Germany	June 2012	RES	5.8kW/5.8kWh 17EA
○		Korea, Jukjeon	December 2012	UPS	500kVA/125kWh 32set

Other solutions for the energy storage issue in the market are proposed by the company S&C Electric. One of their two products is the Purewave Community Energy Storage System[.

This is the only model we will mention since the other model they offer is way beyond our needs.

Figure 30. PureWave CESS

PureWave® Community Energy Storage System [22]

In the event of a power outage, PureWave CES automatically restores power in seconds . . . a major goal of the self-healing Smart Grid. By placing distributed energy storage in close proximity to customers, reliable supplemental power is available to them instantly.

Offering 25 kW for one, t9wo, or three hours, PureWave CES has enough capacity to supply power to a group of customers for the duration of most typical outages. Deployment of these units on a broad scale will significantly improve your customer minutes served — an important index of grid reliability — while greatly reducing your emergency dispatch costs. With its ability to utilize buried distributed batteries, the PureWave CES provides a small footprint that does not change as the energy storage is scaled.

PureWave CES Design Features

- Maintenance-free power electronics comply with IEEE 1547 and UL 1741
- SCADA radio control
- Real-time analog/digital input/output
- Hard-wired bypass available for installation and maintenance
- Status and control panel

Reliability Benefits

Customer Friendly

- Supports multiple customers for hours
- Momentary outage is barely perceptible
- Customers are isolated from repeated operations and transients
- Seamless return-to-normal
- Customers experience “premium” power

System Friendly

- Reduced SAIDI. Power is maintained to customers
- Reduced MAIFI/SAIFI. Customers experience one or zero operations
- After an interruption, system experiences reduced load, reduced inrush
- System can be set for staged return, reducing cold load pickup

Ratings, Dimensions, and Weight	
Active and Reactive Power	25 kVA
Energy	25 - 75 kWh
Secondary Voltage	240 / 120V
Battery	Li-Ion
Round-Trip AC Energy Efficiency	> 85%
Dimensions (CES only)	50"L x 34"W x 31"H
Weight (CES only)	Approx. 750lbs.

For this product, it would be necessary approximately 20 units.

CHAPTER 5: Let's cover the demand!

As we mentioned in chapter 3, we will consider three different cases for our study.

Case 1: One eolic turbine plugged into the grid in a partial or in a total connection (without batteries) supplies the peak of demand (4.7 kW) and exceeds it. Therefore, we choose an eolic turbine of 20-50 kW. The energy that exceeds will be plugged in the network. In case we do a total connection, all the energy goes directly to the network and the energy needed to supply our demand is taken from the network as well.

Case 2: One eolic turbine plugged into the grid in a partial connection (without batteries) supplies the peak of demand (4.7 kW). Therefore, we choose an eolic turbine of 5-8 kW. The energy that exceeds will be plugged in the network.

Case 3: One eolic turbine plus batteries (not plugged into the grid) in a grid off supplies the peak of demand (4.7 kW). Therefore, we choose an eolic turbine of 5-8 kW. The energy will charge a battery of approximately the same power and this will supply the electricity needed for the load.

The reason of this values are because we are working with an approximate 5,32 kW load as Qevap during the most critical part of the year (summer), and as we know we need a refrigeration machine to cool the needed load.

In this chapter it is important to mention the concept of capacity factor.

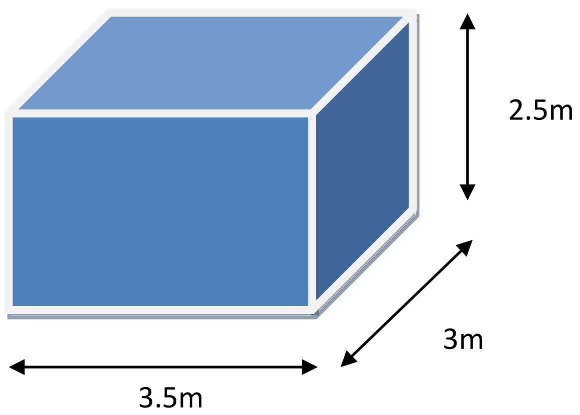
Since wind speed is not constant, a wind farm's annual energy production is never as much as the sum of the generator nameplate ratings multiplied by the total hours in a year. The ratio of actual productivity in a year to this theoretical maximum is called the capacity factor. Typical capacity factors are 20–40%, with values at the upper end of the range in particularly favorable sites. For example, a 1MW turbine with a capacity factor of 35% will not produce 8,760 MWh in a year (1 × 24 × 365), but only 1 × 0.35 × 24 × 365 = 3,066 MWh, averaging to 0.35 MW. Online data is available for some locations and the capacity factor can be calculated from the yearly output.

Unlike fueled generating plants, the capacity factor is limited by the inherent properties of wind. Capacity factors of other types of power plant are based mostly on fuel cost, with a small amount of downtime for maintenance.

According to a 2007 Stanford University study published in the Journal of Applied Meteorology and Climatology, interconnecting ten or more wind farms can allow an average of 33% of the total energy produced to be used as reliable.

5.1 Defining the load:

Now, the shelter is initially situated at Perugia, the internal temperature of it is 20°C, and the size of the shelter is as follows:



The walls are composed by a 5cm layer of polyurethane. The conduction coefficient of this material is k=0.023 W/mK. Although we know that the external conductive coefficient (hext) varies with Nussel number, which depends of the wind conditions on the outside, for our analysis we can consider a constant external conductive coefficient as hext=25W/m2K. The internal coefficient for the shelter is hint=7.7 W/m2K. With all of this values we can calculate the global transfer heating coefficient U, defined as:

$$U = \frac{1}{\frac{1}{h_{int}} + \frac{s}{k} + \frac{1}{h_{ext}}}$$

Where s=5 cm.

This gives us a value of U=0.43 W/m^{2}K. Using the global heat transfer concept q=UAΔT we are able to approximate the amount of energy presented in the fluctuation of winter and summer conditions. Obtaining the following values during the year for Perugia.

	Ta [°C]	Ts [°C]	q = UAΔT [W]	Q [kWh] a month	Q [kWh/m^2] a month	Hours of free cooling (hyphotized)	Internal load 0.5 kWh/m^2 a month	QTOT [kWh/m^2] a month
January	4	20	-365.22	-262.96	-25.04	16	120	95.0
Febbruary	5	20	-342.40	-246.52	-23.48	16	120	96.5
March	8.1	20	-271.63	-195.58	-18.63	14	150	131.4
April	11.5	20	-194.02	-139.70	-13.30	4	300	286.7
May	15.4	20	-105.00	-75.60	-7.20	0	360	352.8
June	20.1	20	2.28	1.64	0.16	0	360	360.2
July	23.1	20	70.76	50.95	4.85	0	360	364.9
Agoust	22.7	20	61.63	44.37	4.23	0	360	364.2
September	19.6	20	-9.13	-6.57	-0.63	1	345	344.4
October	14.1	20	-134.68	-96.97	-9.23	4	300	290.8
November	9.4	20	-241.96	-174.21	-16.59	16	120	103.4
December	5.5	20	-330.98	-238.31	-22.70	18	90	67.3

In this chart we have also hypothesized the amount of free cooling that we will be using during the year. This is, the effect of letting cold air get into the shelter directly without any energy rather than the fan, to maintain the shelter at 20°C.

Therefore, in summer we have a maximum to be refrigerated of 364.9 kWh/m^2 → 3831.45 kWh.

Therefore 3831.45 kWh / 30 days / 24h = 5.32 kW.

We select a refrigeration machine with a COP value of 2,5.

Note: COP value of a frigorific machine is the Coefficient Of Performance of the machine used. This is defined as the quotient between Qevap and Wcomp. Therefore it is the relation between the extracted heated (which is what we are interested in extracting) and the amount of power that we need to insert in the cycle.

Since COP = Qevap / Wcomp the Wcomp is Qevap/2,5, and so the amount of power that we need to apply to the cycle is 5,32 kW / 2,5 = 2,13 kW (during summer).

We select from the market a compressor with an efficiency of 0.9. This means that the amount of electricity we need to apply to the cycle on summer is approximately 2.13/0.9 ≅ 2.35 kWe.

This is the maximum value that we'll take into account in order to choose the power of our eolic turbine. Since we expect the load to be duplicated in the future, we will consider a peek of electrical power to be fed as $2.35 \cdot 2 = 4.7kWe$.

After choosing the turbine, we need to see if we are able to produce the annually amount of energy we need (30 MWh) by analyzing the power curve of the turbine plus the wind conditions of the place. The power we need to apply is $\frac{30MWh/2.5}{0.9} \cong 13.3MWh/year$. Since load is duplicated in the future, we will consider a 26.6 MWhe/year for dimensioning.

Note: Radiation presented throughout the hole year is very low in comparison to the 30MWh a year. Radiation value for the dimensions of the shelter and the sun conditions in Perugia barely reaches an approximate value of 150 kWh/year = 0.15MWh/year, negligible for our economical analysis.

In order to understand the process that we will use to select the required eolic turbine we will define the amount of energy that this turbines are able to produce. For this, we will study the Power Curve of the turbine with the Accumulative Wind Velocity

Let's take a look at the following:

5.2 Produced energy over a year for a wind turbine

[23] If we combine the power characteristic curve of an eolic turbine with the accumulative wind velocity curve in a given place as we can see in figure 31, we can obtain the amount of energy over a year for each turbine. This is going to tell us which wind turbines are the ones that can supply our load.

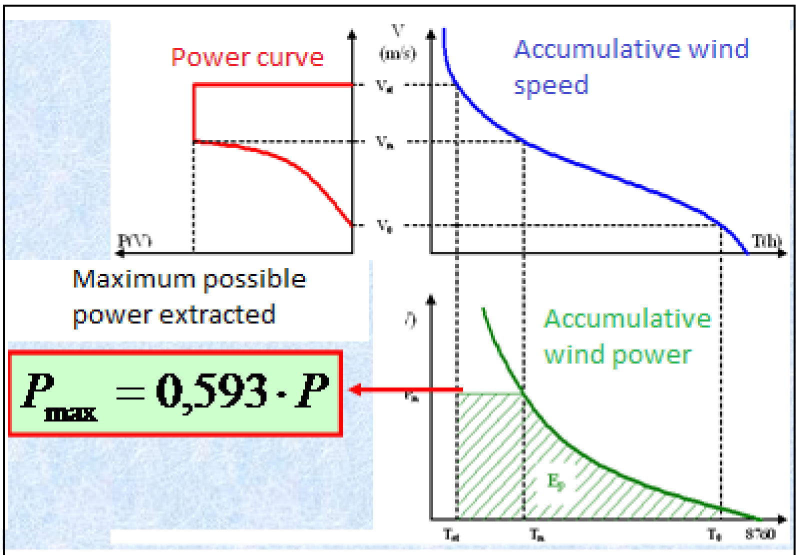


Figure 31. In this figure we can see how to obtain the accumulative wind power

What does the accumulative wind velocity curve means?

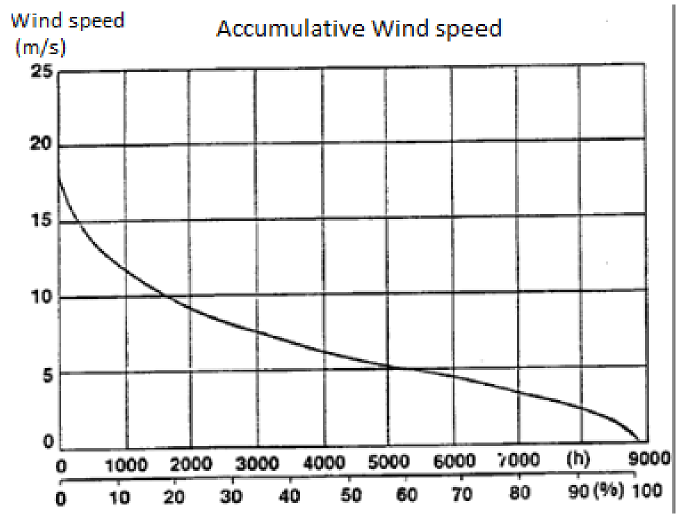


Figure 32. Example of accumulative wind curve

This curve as we can see in figure 32, states the total amount of hours for which a certain velocity is exceed. For example: a velocity of 0 m/s is exceeded in 8760 hours a year. A velocity of 5m/s is exceeded in 5000 hours a year. Or for example, at approximately 1750 hours a year, the velocity of the wind exceeds the value of 10 m/s.

We need to obtain the characteristic Power Curve and the Accumulative Wind Velocity so we can get the desired curve.

The Power Curve will be given by the mini eolic turbine we choose. Therefore it depends on the quality of the turbine and it can be obtained by the manufacturer of it.

Meanwhile for the Accumulative Wind Velocity in Perugia we have the following:

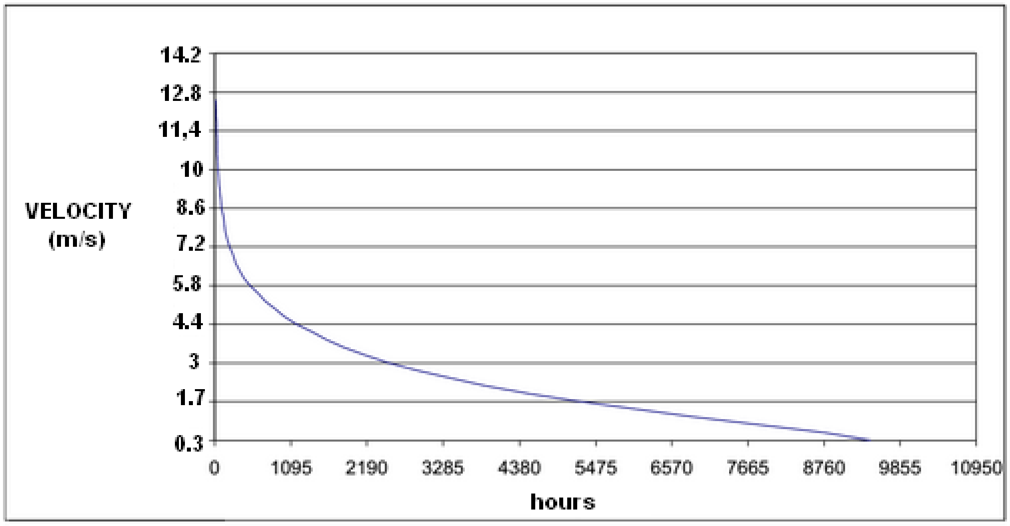


Figure 33. Accumulative wind speed curve in Perugia

To analyze this we will first explain the procedure on how to obtain the total amount of energy in a hole year having both the power curve of the turbine and the accumulate wind velocity graphs.

Let's for example choose the Windspot 7.5 kW.

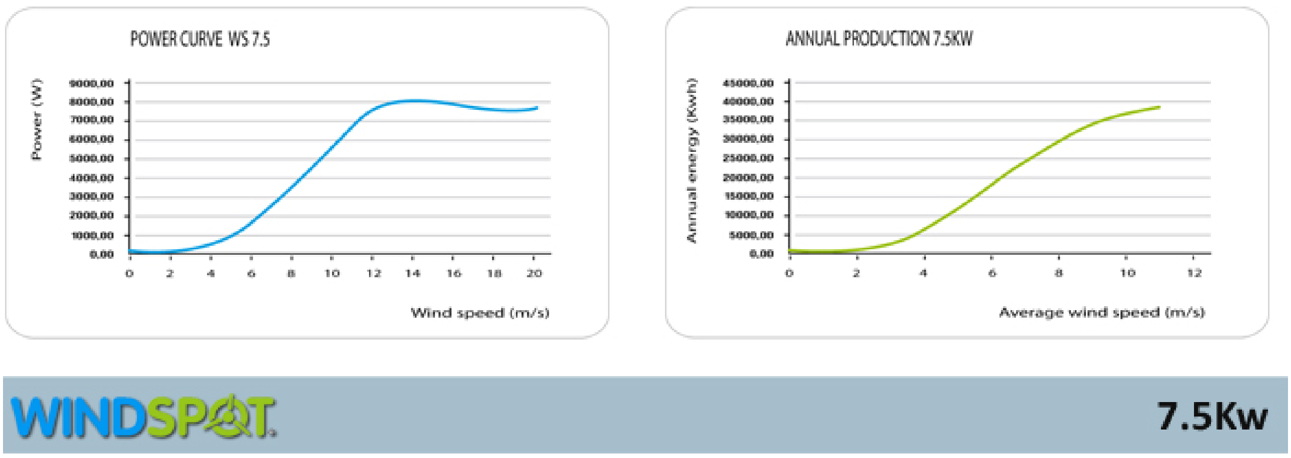
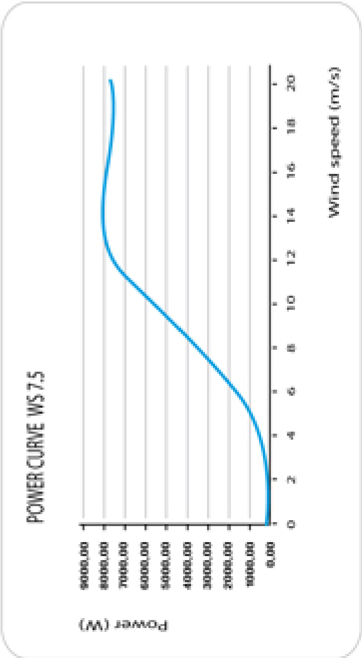


Figure 34. Power curve and annual production for the WINDSPOT 7.5KW.

Combining both graphs as showed

in figure 35



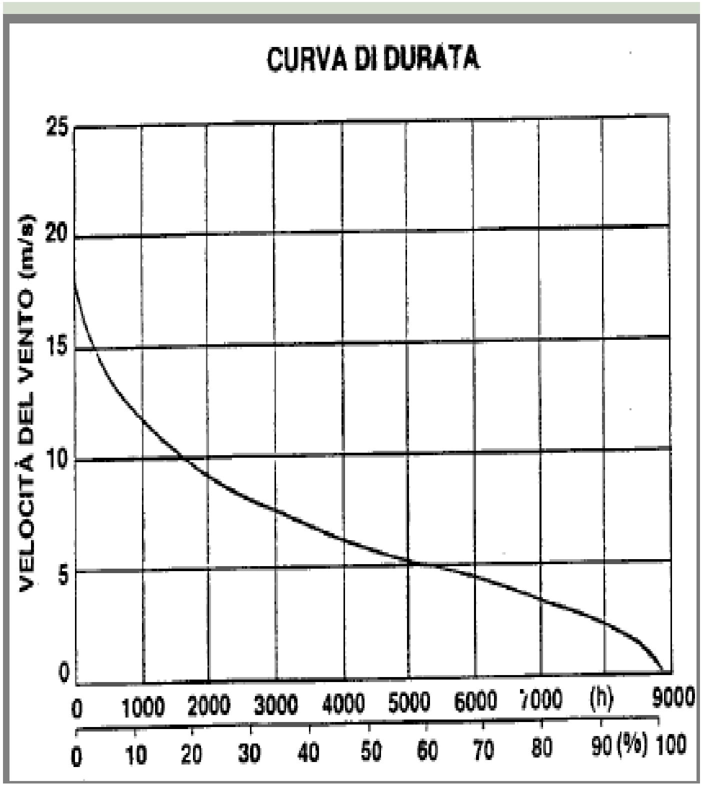


Figure 35.

we'll obtain the accumulative power by simply multiplying the value of the Power with the corresponding amount of hours.

Taking 20 values from each graph we get the following graph

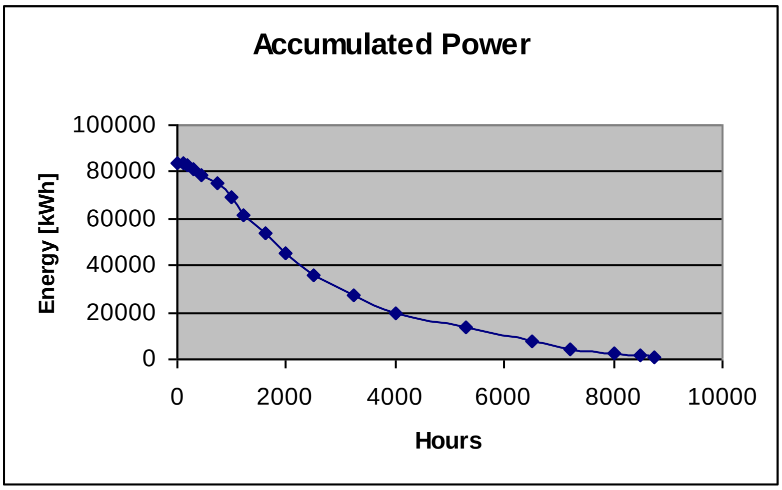
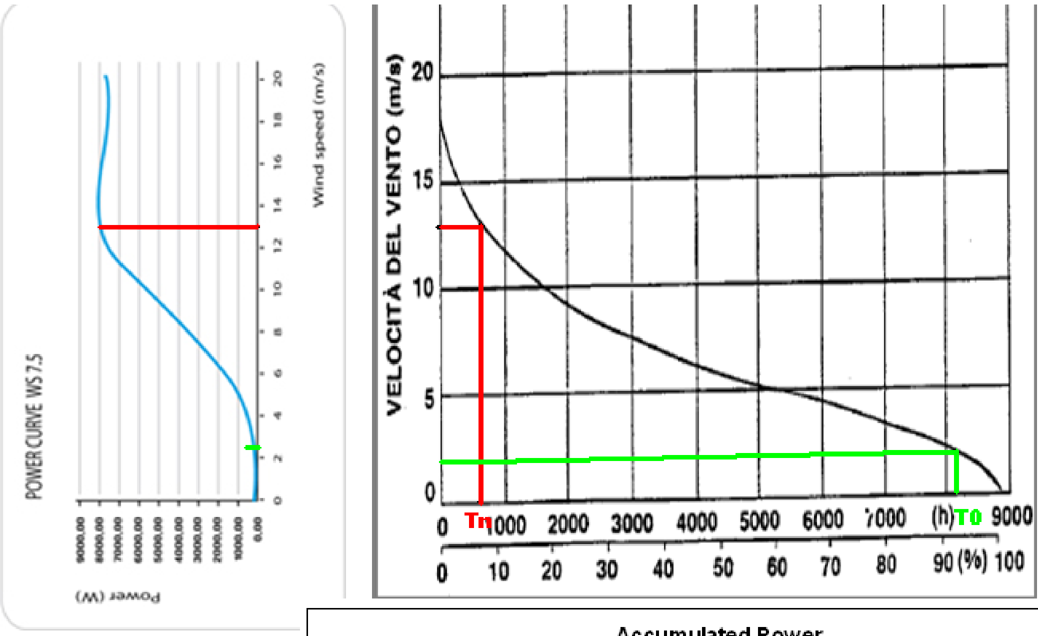


Figure 36. Accumulated power was obtained.

Looking at all the graphs together we'll be able to know that the maximum energy possible obtained for this wind turbine in this specific place is around 80 kWh.



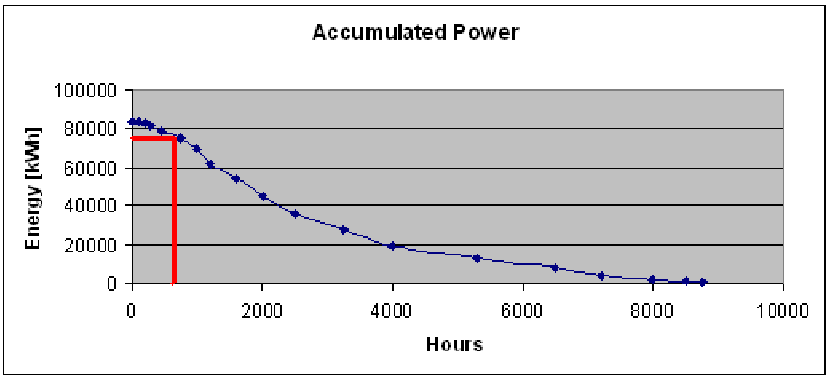


Figure 37. Combining the accumulated wind speed with power curve to obtain the accumulated power

We need to know what amount of energy are we capable to obtain in a hole year with this conditions. Therefore we need to integrate the hole area behind the Accumulated power through all the year. We'll do this by discretizing the graphic in small intervals of about 0.5 m/s.

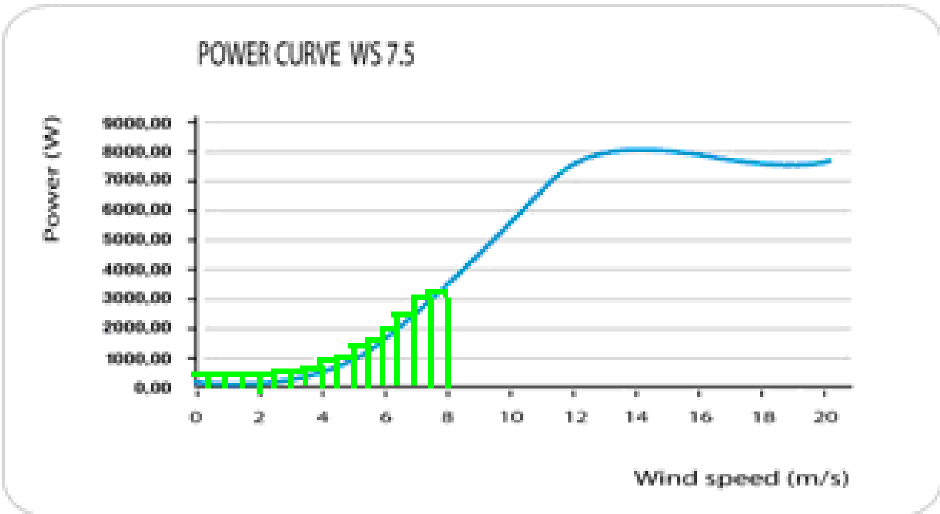
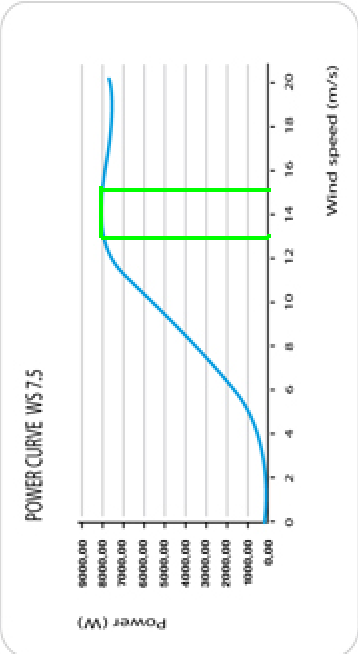


Figure 38. Discretizing the power curve.

This way for example



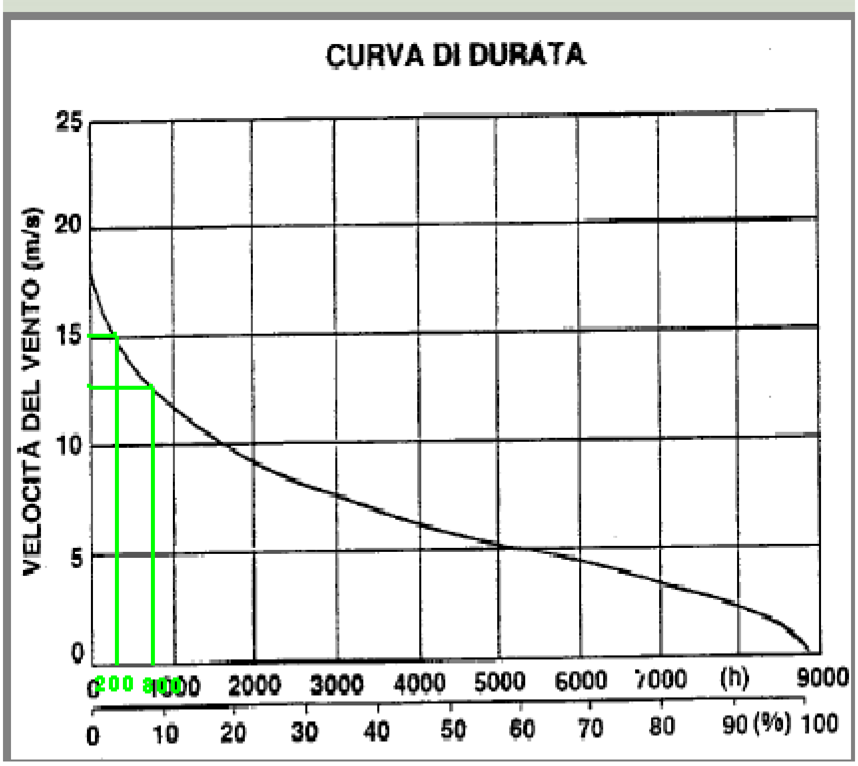


Figure 39. Interpretation for the combined graphs

V[m/s]	Power [kW]	Δt [h]	Energy [kWh]
16-20	7.7	100	770
13-16	8	650	5200
12.5-13	7.85	100	785
12-12.5	7.7	100	770
11.5-12	7.5	150	1125
11-11.5	7	100	700
10.5-11	6.4	200	1280
10-10.5	6	150	900
9.5-10	5.3	300	1590
9-9.5	4.9	300	1470
8.5-9	4.5	150	675
8-8.5	4	150	600
7.5-8	3.5	200	700
7-7.5	2.9	500	1450
6.5-7	2.5	600	1500
6-6.5	2	500	1000
5.5-6	1.7	500	850
5-5.5	1.3	500	650
4.5-5	1	1000	1000
4-4.5	0.7	800	560
3.5-4	0.5	700	350
3-3.5	0.4	500	200
2.5-3	0.3	200	60
2-2.5	0.2	200	40
0-2	0.1	110	11
	TOTAL	8760	24236

We see that for approximately for (800-200=) 600 hours of the year we can get a Power of 8 kW. This means that 8000W*600h= 4800kWh in this period of time. Doing this we'll obtain the following chart.

We are able then to produce with this eolic turbine an amount of energy of approximately 24 MWh a year for this wind conditions.

The previous was shown as a mode of example to get to know the process on how we obtain the total amount of Energy possible with a certain wind turbine.

Applying this for the specific case of Perugia, using the same wind turbine (WINDSPOT 7. 5kW), we obtain from the data analysis that the possible total amount of energy that we can get during a year is around 4MWh.

This result is clearly discouraging, since we are not even covering the 1/6 of the demand.

Repeating the process with the T30proS (with a rated power of 30 kW) we obtain a result of approximately 23 MWh. Not covering the demand as well (26MWhe).

To cover the total demand we would need to install a 50kW wind turbine like for example the AEOLOS-H 50KW, giving us a total amount of energy of 47 MWh.

In chapter 6 we will analyze the economic impact of this option, but as we can assume, it's not going to be profitable at all due to the high price of buying wind turbines greater than 30kW and the bad wind conditions in Perugia.

5.3CHOOSING A MORE WINDY PLACE:

[26]By choosing another place, we'll need to modify the load as well due to different temperature conditions.

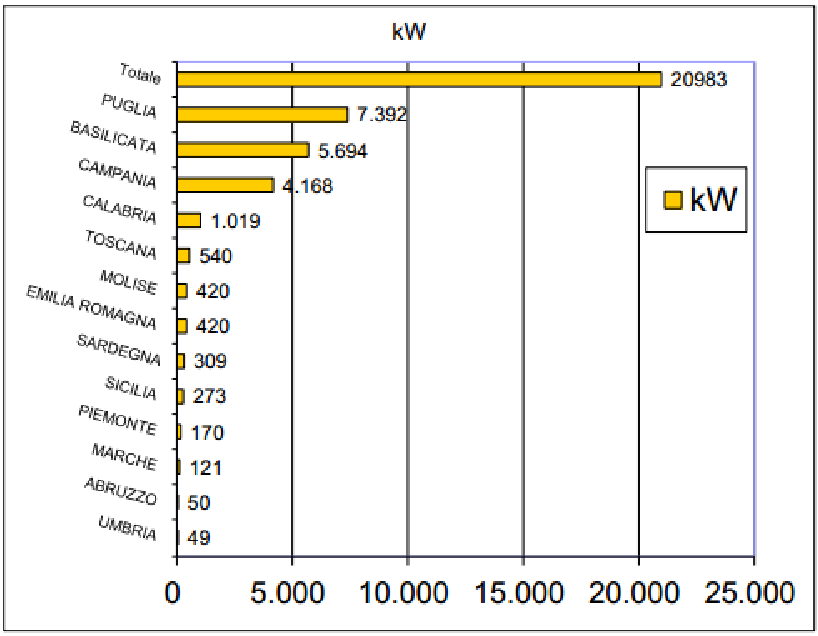


Figure 40.Installed KW at different locations in Italy

More than 90% of the turbines are less 80 kW in size. The majority of the capacity, 70%, is installed in the southern provinces, 25% in the central region, and only 5% in the mountainous north.

And so, from the best places in Italy to install an eolic turbine, we will be working with the data from Brindisi at Puglia, Italy. The new load chart will be as follows:

	Ta [°C]	Ts [°C]	q = UAΔT [W]	Q [kWh] a month	Q [kWh/m^2] a month	Hours of free cooling (hyphotized)	Internal load 0.5 kWh/m^2 a month	QTOT [kWh/m^2] a month
January	7 10 12.9	20	-365.22	-262.96	-25.04	10	210	194,3
Febbruary	7.1 10.4 14.3	20	-342.40	-246.52	-23.48	10	210	195,0
March	9.7 12.5 15.4	20	-271.63	-195.58	-18.63	8	240	228,3
April	12.4 15.8 19.3	20	-194.02	-139.70	-13.30	1	345	338,4
May	15.4 19.1 22.5	20	-105.00	-75.60	-7.20	0	360	358,6
June	18.2 21.8 24.6	20	2.28	1.64	0.16	0	360	362,8
July	22.2 25.4 28.1	20	70.76	50.95	4.85	0	360	368,5
Agoust	23.6 26.9 29.9	20	61.63	44.37	4.23	0	360	370,8
September	18.8 22.7 26.1	20	-9.13	-6.57	-0.63	0	360	364,2
October	15.7 18.6 21.8	20	-134.68	-96.97	-9.23	0	360	357,8
November	10.9 14.9 18.2	20	-241.96	-174.21	-16.59	5	285	277,0
December	7.5 10.5 12.8	20	-330.98	-238.31	-22.70	10	210	195,1

Now the total load to be refrigerated has increased to 37913.9 ≈ 38MW since we are in a warmer place. Average temperatures for each month have increased and therefore the hypothesized hours for free cooling have decreased.

As well the maximum value is still in summer at 370.8 kWh/m^2.

Therefore, 370.8 kWh/m^2 → 3893.4 kWh.

3893.4 kWh / 30 days / 24h = 5.4 kW.

Since COP = 2.5 → 5,4 kW / 2,5 = 2,13 kW (during summer).

η_{comp}=0.9 → 2.16/0.9 ≅ 2.4 kWe.

This is the maximum value that we'll take into account in order to choose the power of our eolic turbine. Since we expect the load to be duplicated in the future, we will consider a peek of electrical power to be fed as 2.4 · 2 = 4.8kWe.

There's no appreciated difference with the previous case at Perugia for the selection of the eolic turbines.

The annually amount of energy we need (38 MWh) to apply is

$$\frac{38MWh/2.5}{0.9} \cong 16.9MWhe/year$$

Since load is duplicated in the future, we'll consider 34 MWhe/year for dimensioning.

So now, the information we could find with respect to Brindisi is the curve that represents its wind velocities with the frequency all over the year showed in figure 41.

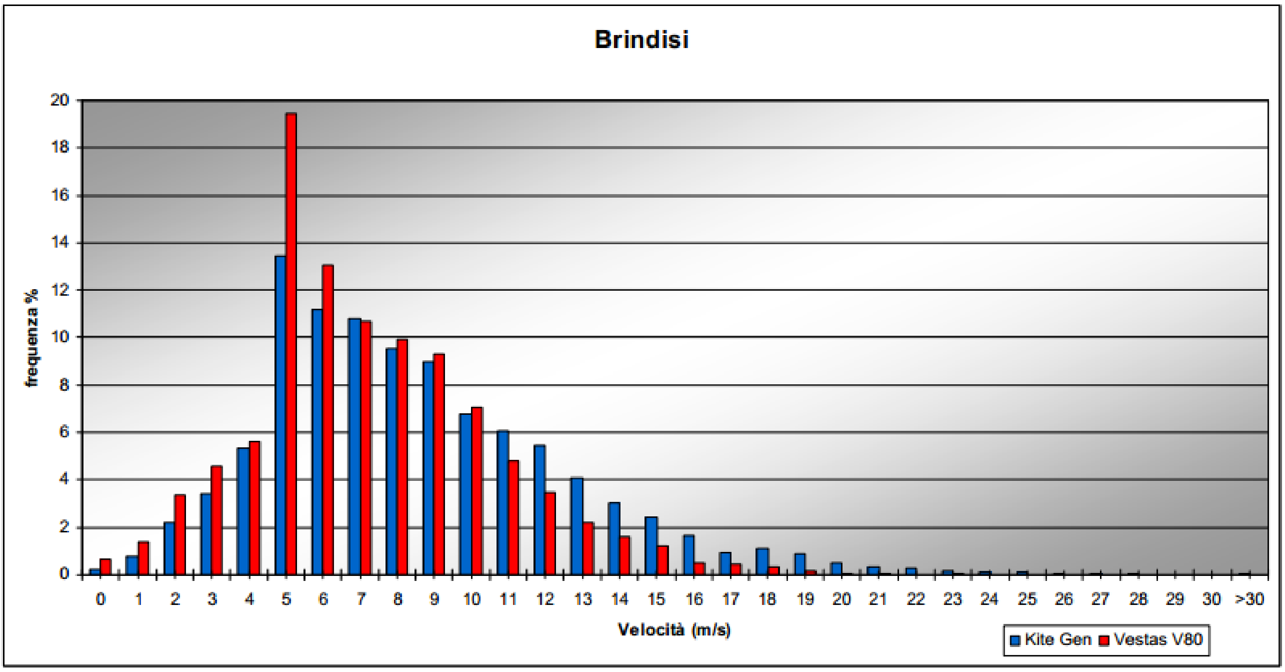


Figure 41. Wind speed frequency (in %) at Brindisi, Puglia.

Vestas V80 in red represent the values for the wind speeds at 40-120 meters.

Kite Gen in blue represent the values for 200-800 meters from the ground.

We will work then with Vestas V80 values which gather our case for our project to build directly the accumulative wind speed curve, which is shown in figure 42.

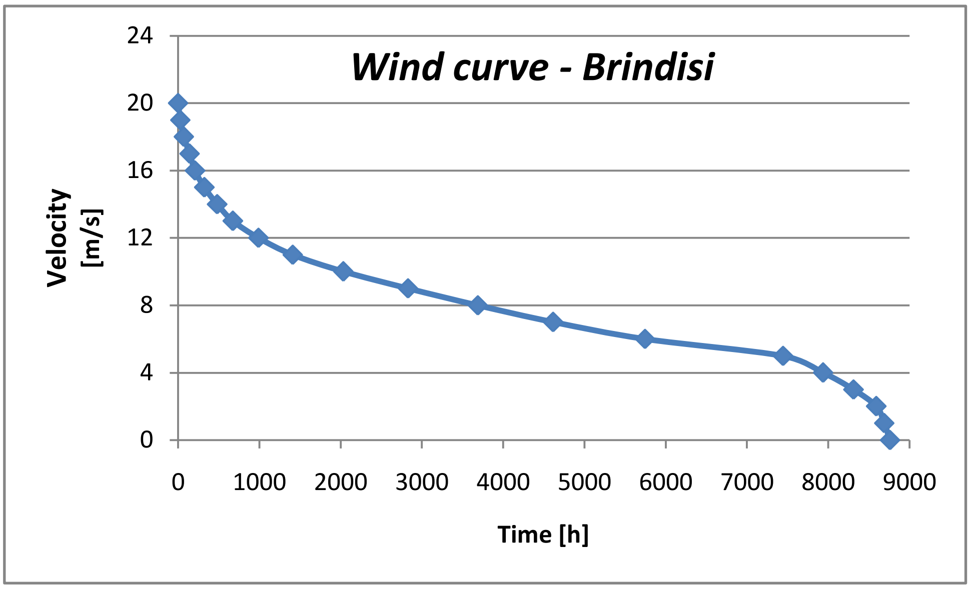


Figure 42. Accumulated wind curve for Brindisi, Puglia.

Let's evaluate now under these conditions which wind turbine covers the demand.

First let's try again with the WINDSPOT 7.5 kW. Working with the same power curve we worked before, with this wind turbine, under Brindisi wind conditions we are capable of obtaining 29,584 MWhe/year. Not enough to cover the 34 MWhe/year needed.

We choose then the AEOLOS-V10 kW with its power curve shown in figure 43.

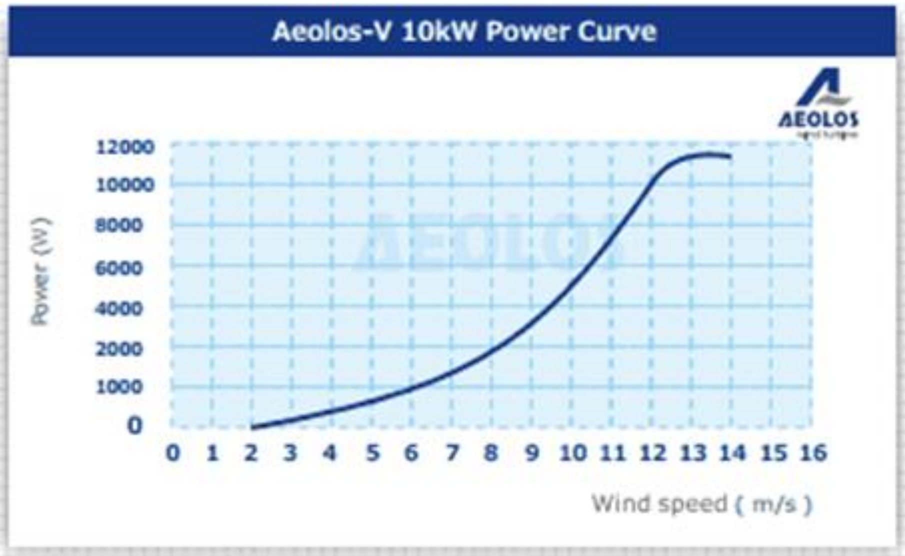


Figure 43. Power curve for AEOLOS-V 10KW.

Obtaining 23.5 MWhe/year. Even less than what we could possibly obtain with the WINDSPOT 7.5KW. Clearly not enough.

But why did this happened if it has a greater power than the WINDSPOT 7.5 KW?

As we saw previously, the total amount of Energy that the wind turbine can develop not only depends of the maximum power that the turbine can reach, but also the range of speeds that it works with. In this case, the range of speeds it works with is clearly less than th one before ([2-14 m/s] front [0-20 m/s]). We need therefore to look for other options.

Note: Considering this aspect, the wind turbine Bornay 6kW could produce then more power than WINDSPOT 7.5kW. But after making the analysis we obtained that with that wind turbine we were able to produce only 27.3 MWhe/year, not covering the demand.

So we finally select the AEOLOS-H10 KW with the power curve shown in figure 44.

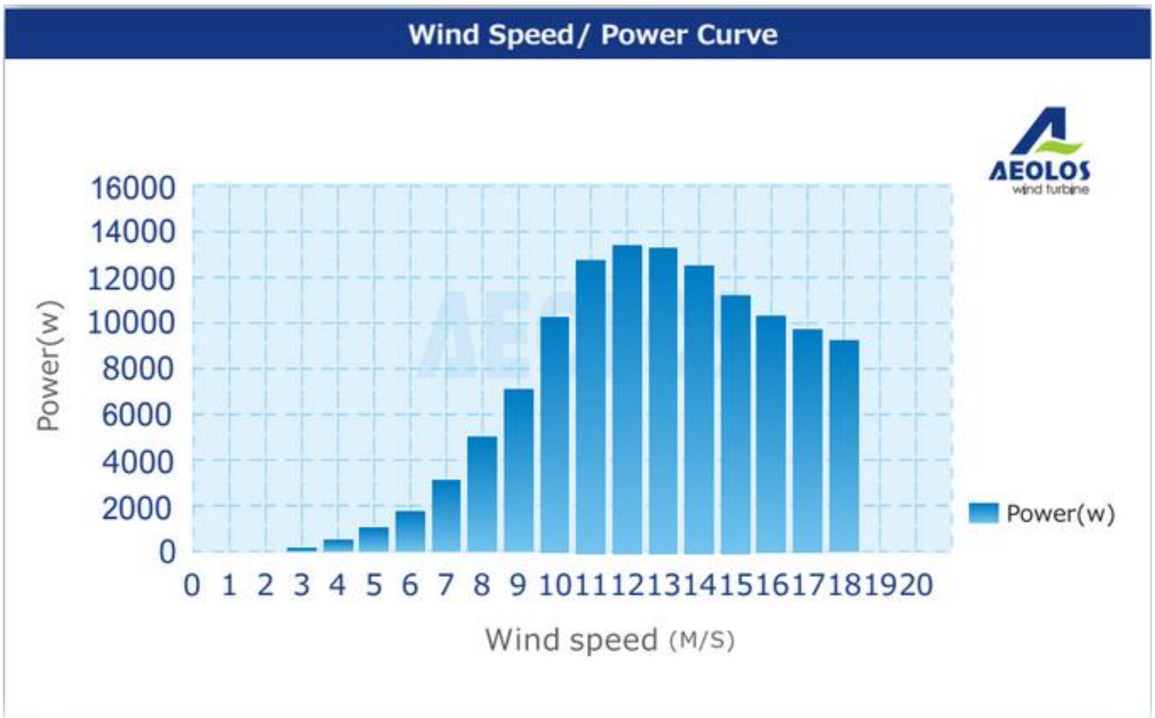
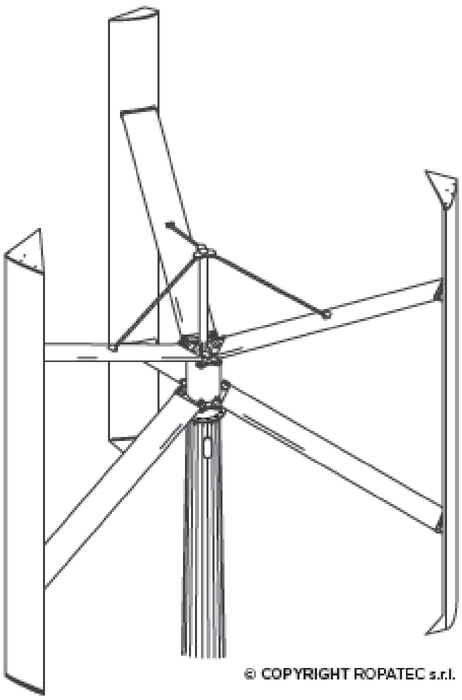


FIgure 44. Power curve for the AEOLOS-H 10KW.

With which we are able to produce approximately 46 MWhe/year. Enough to statisfy our demand.

There's also another option in the market we need to analyze, and is MISTRAL 10KW. Its power curve can be seen back in chapter 3. And results obtained with that wind turbine are a total amount of energy among a year of approximately 53 MWhe/year.

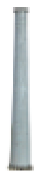
Since we didn't get any feedback about prices for the companies ESPE Group and FREEWIND, we will cover case number 1 by analyzing results given by the T20proS On Grid & T30proS On Grid from the company ROPATEC Vertical Energy. We will later analyze if the price difference between the two of them is worth it to pay (95.000€ vs. 90.000€). T30proS offers the following:



T30pro / T30proS

Turbina eolica ad asse verticale con generatore 30 kW a magneti permanenti a presa diretta

T30 Pro On-Grid	Incluso nella fornitura
WT30.3.G30	Turbina eolica con generatore sincrono a magneti permanenti a presa diretta
	Sistema di frenatura di sicurezza
	Inverter On-Grid
	Quadro elettrico generale
	Sensore Setac
	Contollore PLC con livello sicurezza SIL-3
	Anemometro
	Dispositivo di interfaccia
	Protezioni da sovratensione
	SMDR
WTM.30.24	Monopalo 24m
WTMA.30.24	Sistema di ancoraggio per monopalo
WTMS.30.24	Scaletta + ballatoio per palo
PREZZO TOTALE	**€ 95.000**



Monopalo Fe510 zincato a caldo altezza 24m.

With the following Power Curve shown in figure 45.

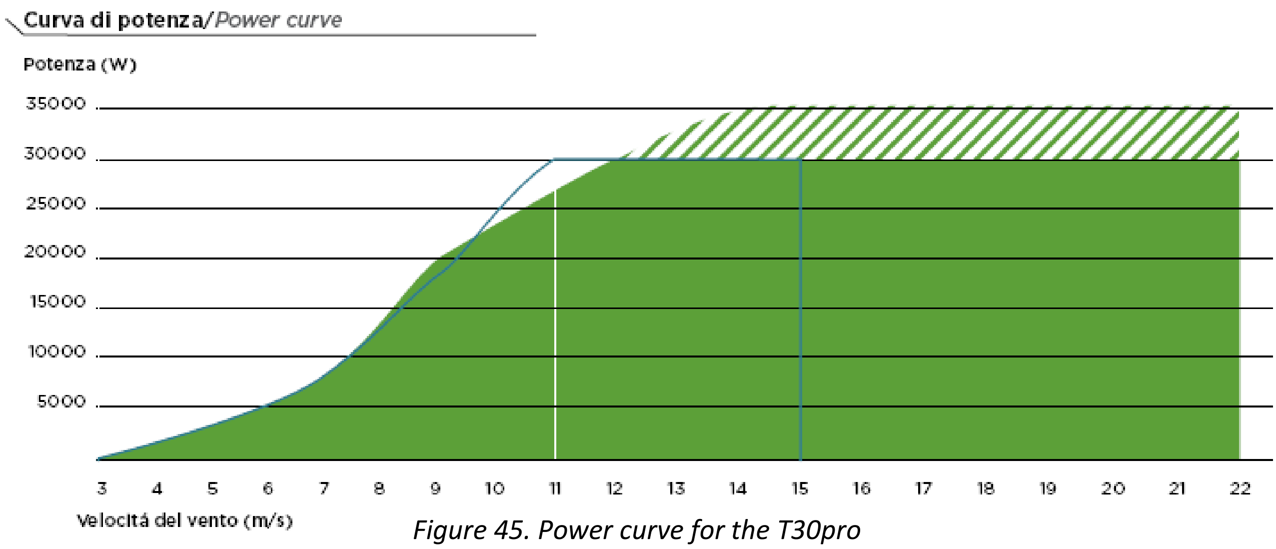
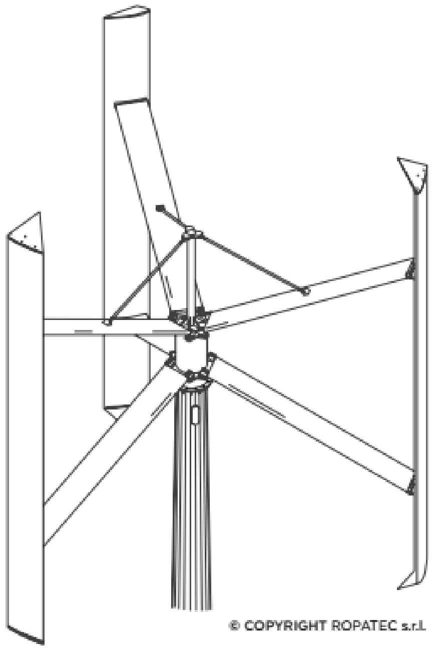


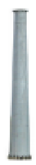
Figure 45. Power curve for the T30pro

Realizing the same analysis done for cases 2 and 3 we obtain that for the wind conditions presented in the zone, and the power curve given by the eolic turbine, the maximum amount of energy we get with this turbine is 103,114 MWhe/year.

With this turbine we perfectly cover the demand and we also are able to sale back to the grid approximately 50 MWh in the course of a year. In chapter 6 we will analyze if this option is feasible or not.

Instead, results thrown with the T20proS are 92 MWhe/year with the following characteristics and power curve shown in figure 46.





Monopalo Fe510 zincato a caldo altezza 24m.

T20pro / T20proS

Turbina eolica ad asse verticale con generatore 20 kW a magneti permanenti a presa diretta

T20 Pro On-Grid	Incluso nella fornitura
WT20.3.G30	Turbina eolica con generatore sincrono a magneti permanenti a presa diretta
	Sistema di frenatura di sicurezza
	Inverter On-Grid
	Quadro elettrico generale
	Sensore Setac
	Contollore PLC con livello sicurezza SIL-3
	Anemometro
	Dispositivo di interfaccia
	Protezioni da sovratensione
	SDMR
WTM.30.24	Monopalo 24m
WTMA.30.24	Sistema di ancoraggio per monopalo
WTMS.30.24	Scaletta + ballatoio per palo
PREZZO TOTALE	**€ 90.000**

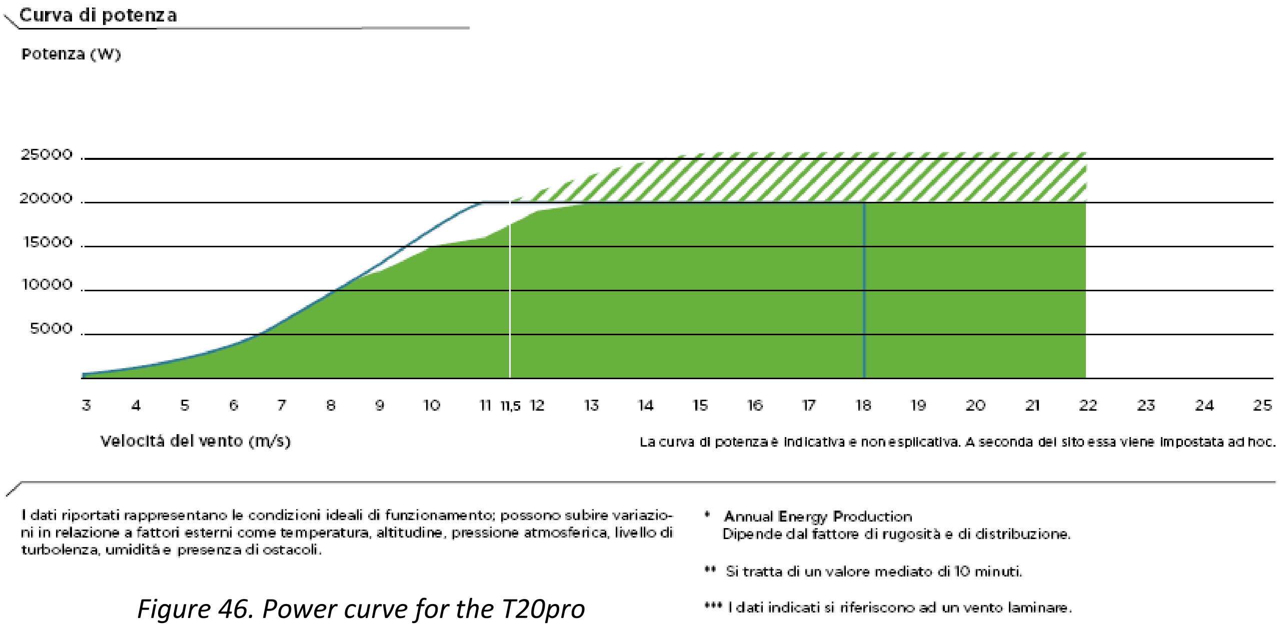


Figure 46. Power curve for the T20pro

We will also analyze the options Aeolos-H 20kW, 30kW and Aeolos-H 50kW.

The power curve for these models are:

For Aeolos-H 20kW (figure 47)

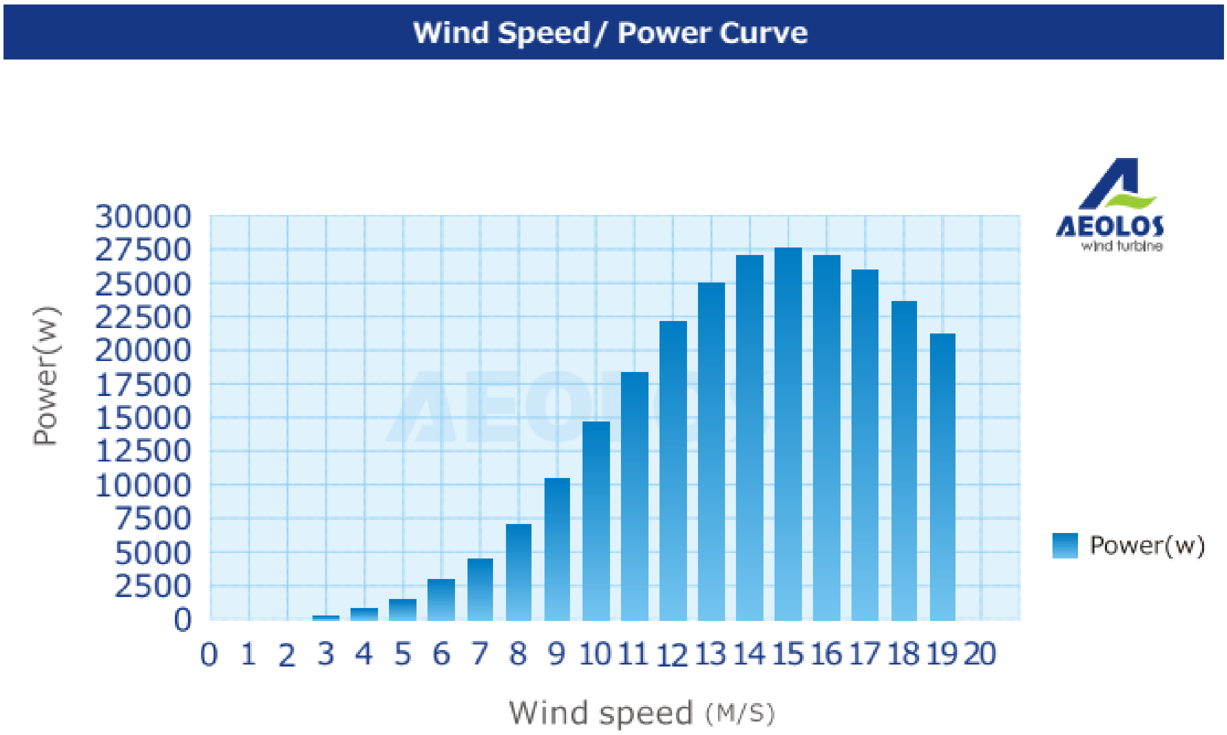


Figure 47. Power curve for the AEOLOS-H 20KW.

For Aeolos-H 30kW (figure 48)

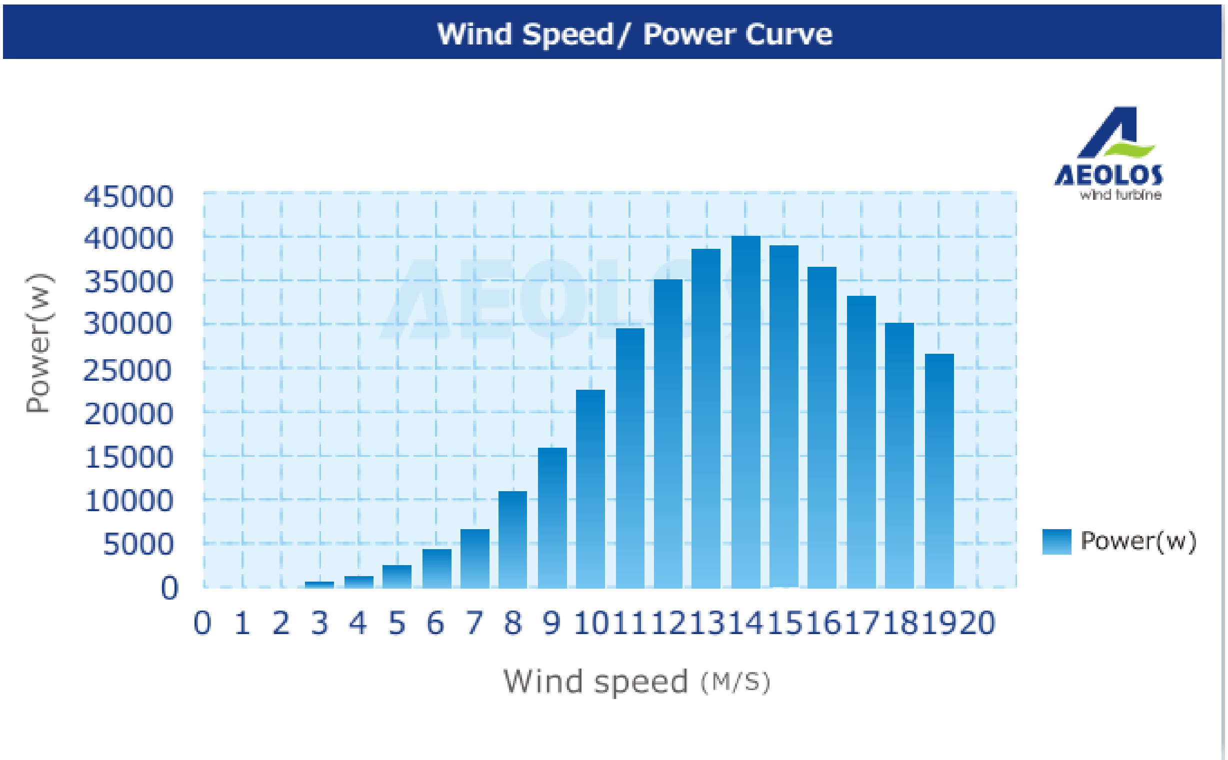


FIgure 48. Power curve for the AEOLOS-H 30KW.

And for the Aeolos-H 50kW (figure 49)

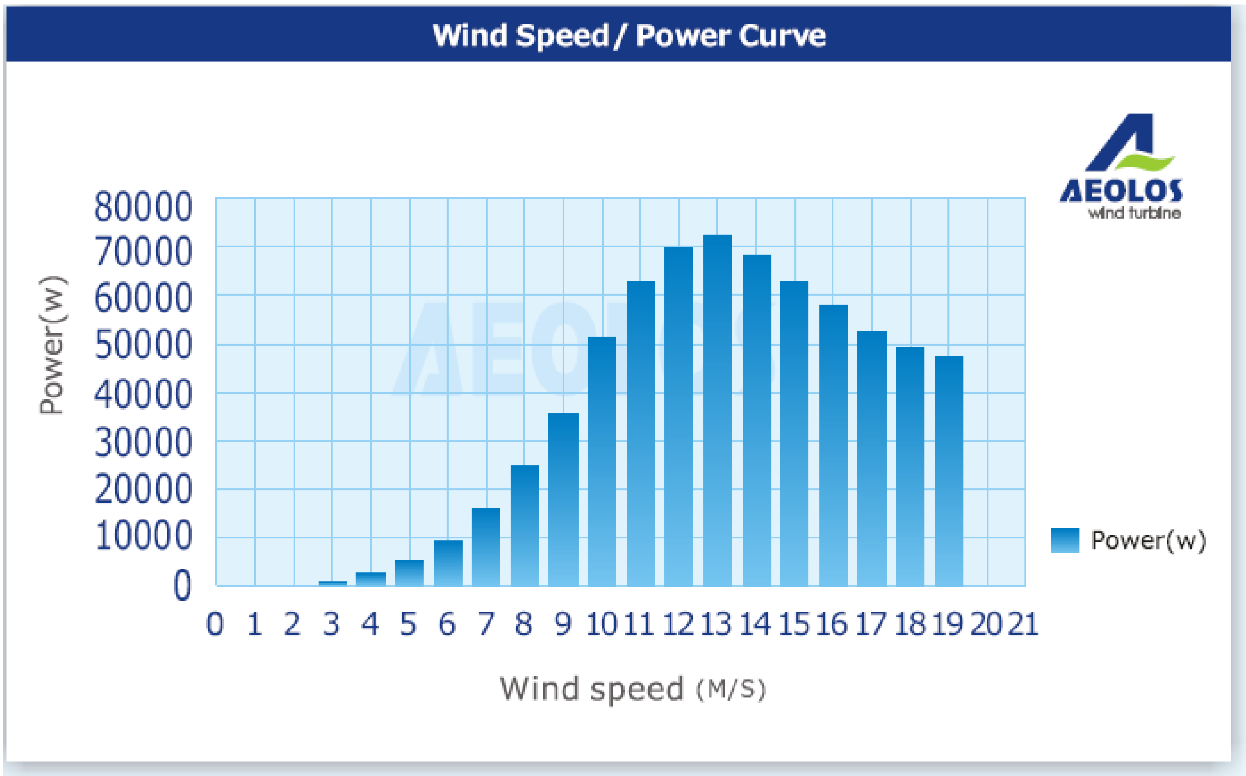


FIgure 49. Power curve for the AEOLOS-H 50KW.

Results thrown for each of the models are:

Model	Energy a year
Aeolos-H 20kW	75 MWhe
Aeolos-H 30kW	114,22 MWhe
Aeolos-H 50kW	234,82 MWhe

There are also some other options in the market that can be analyzed such as those found in chapter 3 from the company RENOVA WIND ENERGY. By analyzing each of their models (which Power Curve can be found in chapter 3) we obtain the following results.

Model	Energy a year
WINDTECH 20KW	107,6 MWhe
WINDTECH 30KW	149 MWhe
Bonus 23-60 (60kW)	294 MWhe
Largerwey 18-60 (60kW)	266,64 MWhe
Nordtank 21-60 (60kW)	251,4 MWhe
Nordtank 25-60 (60kW)	356 MWhe
VESTAS V17-60 (60kW)	302,17 MWhe
VESTAS V20-60 (60kW)	273,38 MWhe

CHAPTER 6: INCENTIVES, MARKET

Now we are in the decisive part of our thesis. After choosing which eolic turbines can cover our demand it's time to decide which is the most feasible solution to our project. In order to do this we will compare money invested (including initial costs, and subsequent costs), money perceived (including incentives and grid selling) & finally the payback time in each of the cases.

Regarding incentives, we selected wind turbines with lower nominal power than 60kW because they provide the added benefit of incentives without enrolling with the registry of admission and with simplified authorization requirements compared to higher powered units. It is stated by the GSE[24] ("Gestore dei Servizi Elettrici"), that our minieolic plant in Italy would perceive a feed-in tariff of 0,291 €/kWh, 0.268 €/kWh for 15 years when the nominal power of the installation is less than 20 kW and 200 KW respectively (Ministerial Decree of December 18, 2008 and the Finance Act 2008) as seen in figure 50. This is, for each kWh we inject into the network, we will receive back 0,291 €.

Italian Feed-in Tariffs for Small Wind 2012				
Tariff Year	2011			
		Tariff	1.241	1.251
	Years	€/kWh	CAD/kWh	USD/kWh
Wind <200 kW	15	0.30	0.37	0.38

Renewable Tariffs in Italy 2013 Note: This is only a summary from program descriptions in English & Italian.						
	Years	Base Tariff €/kWh	1.241 CAD/kWh	1.251 USD/kWh	Type	Registry
Wind onshore						
>1 kW<20 kW	20	0.291	0.361	0.364	Fixed or Premium	Direct
>20 kW<200 kW	20	0.268	0.333	0.335	Fixed or Premium	Registry >60 kW

Figure 50. Feed in tariffs for 2012 and 2013 for small wind energies in Italy [2][25].

Nevertheless, nowadays small wind energy in Italy is nearly 50% more expensive than the most expensive solar PV per kilowatt-hour of generation. Here is why we add in figure 41 as an informative title the tariffs for solar photovoltaic plants.

Solar Photovoltaic Tariffs in Italy 2013 Selected Tranches						
		Tariff	1.241	1.251		
	Years	€/kWh	CAD/kWh	USD/kWh	Type	Registry
Photovoltaics						
Rooftop all inclusive						
>1 kW<3 kW	20	0.208	0.258	0.260	Fixed tariff	Direct
>3 kW<20 kW	20	0.196	0.243	0.245	Fixed tariff	Registry >12 kW
>20 kW<200 kW	20	0.175	0.217	0.219	Fixed tariff	Registry

Figure 51. Feed in tariffs for 2013 for solar phtovoltaic energies in Italy[2][25].

Though in recent years the minimum remuneration to consider an investment in wind power has always been not less than 150 € / MWh, the mechanism of auctions showed instead how there are workers ready to invest with an incentive of 100 € / MWh. Furthermore, the reduction of tariffs, inherent in the bidding mechanism, required to select and prioritize only those sites with high wind speeds.

According to Alessandro Giubilo, president of ASSIEME, the incentive of 0,291 €/kWh it's a very good incentive, but not enough to cover the management cost of those small eolic plants (1-3kW). On the contrary, it proves to be profitable especially for machines with larger power than 10kW, offering a 20 years economic returns of around 10-12% per annum. Same situation for bigger machines from 21 to 60 kW, with a lightly lower incentive of 0,268 €/kWh always for 20 years. Here the investment has a similar return but they also have a higher cost of purchasing the complete system, as well as more difficulty obtaining credit from the banks.

As we said before, we don't consider machines over 60kW-200kW because they don't guarantee the automatic admission to the incentive, though they'd have the same incentive tariff.

For those small eolic machines (1-3kW), due to their high operating costs of the dedicated counter, the connection mode is more likely to be a Grid on - net metering ("scambio sul posto") without any incentive, but can still take advantage of the income tax reduction of the Irpef of the 50% over 10 years until the end of June 2013.

Let's now talk some more about the different configurations with the grid as found in the GSE, extending the information exposed in chapter 3. Information that we can find inside the GSE in order to clarify more the actual situation in Italy for mini-eolic.

6.1 Simplified purchase & resale arrangements ("ritiro dedicato")

GSE has offered simplified purchase & resale arrangements ("ritiro dedicato") to small producers since 1 January 2008.

Under these arrangements (AEEG's Decision 280/07), producers sell the electricity generated and to be injected into the grid to GSE, instead of selling it through bilateral contracts or directly on IPEX.

An agreement is entered between the producer and **GSE**, whereby GSE:

- purchases and resells the electricity to be fed into the grid at the zonal price or at a **minimum guaranteed price**;
- on behalf of the producer, transfers the fees for the use of the grid (dispatch and transmission fees) to distributors and to the TSO.

Eligible parties

Producers with:

- plants having a nominal apparent power of less than 10 MVA: RES plants or hybrid plants for the portion of electricity generated from RES;
- plants of any capacity using the following RES
- wind; solar; geothermal; waves; tides; hydro (run-of-river only);
- plants with a nominal apparent power of less than 10 MVA: non-RES plants or hybrid plants for the portion of electricity generated from non-RES;
- plants having a nominal apparent power greater than or equal to 10 MVA: plants using RES other than wind, solar, geothermal, waves, tides and hydro (run-of-river only), provided that they are owned by a self-producer (as defined in article 2, para. 2, Legislative Decree 79/99).

Guaranteed minimum prices

The price applied to the electricity purchased by GSE and injected into the grid is the "**average zonal price**" (see figure 53), i.e. the average monthly price per hourly band which is set on IPEX for the market area to which the plant is connected.

Producers with small-sized plants (with a nominal electrical capacity of up to 1 MW) benefit from “**guaranteed minimum prices**” (see figure 52) for the first 2 million kWh per year and they may get more if the hourly zonal prices prove to be more advantageous. The guaranteed minimum prices are updated annually by **AEEG**. At the end of each year, GSE makes adjustments for plants in respect of which the revenue associated with the hourly zonal prices proves to be higher than the one resulting from the application of the minimum guaranteed prices.

Annual rate change in consumer prices for households of workers and employees detected by ISTAT in 2013 compared to 2012: 1,10%.

Guaranteed minimum prices for 2014:

Source	Quantity of electric energy retreated (annual base)	Guaranteed minimum prices [€/MWh]
Eolic	Up to 1.500.000 kWh	48,9
Solar Photovoltaic	Up to 1.500.00 kWh	38,9

Figure 52. Guaranteed minimum prices in Italy for 2014.

Average zonal price [€/MWh]

February 2014

		Brindisi	Central Nord Zone	Central South Zone	North Zone	Sardegna Zone	Sicilia Zone	South Zone
Band	F1	48,21	45,62	45,2	49,63	50,38	76,61	46,56
	F2	55,98	56,11	53,06	57,88	55,88	95,03	54,42
	F3	39,53	34,69	33,05	41,68	36,72	54,76	34,65

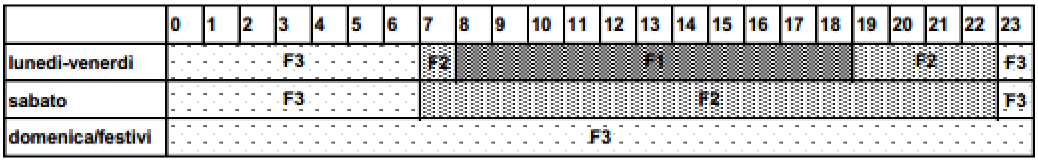


Figure 53. Average zonal price in Italy for 2014.

The average monthly price is calculated as the average, for each time band, of the time zone price weighted with the quantity of overall sold energy on each dispatching managed by GSE.

Compatibility with other support schemes

The simplified purchase & resale arrangements are not compatible with net metering ("scambio sul posto") and with the all-inclusive feed-in tariff.

6.2 Net metering service ("scambio sul posto")

Since 1 Jan. 2009, AEEG (Decision ARG/elt 74/08, as subsequently amended and supplemented by Decision ARG/elt 186/09) has assigned to GSE the management of the net metering service (scambio sul posto). This service is activated at the request of interested parties. Under the service, the electricity generated by a consumer/producer in an eligible on-site plant and injected into the grid can be used to offset the electricity withdrawn from the grid; acting as a sort of virtual storage system. GSE pays a contribution to the customer based on injections and withdrawals of electricity in a given calendar year and on their respective market values.

Those plants with an average annual production lower than 20kW fed by renewable energies, and those from 20kW to 200kW that started operation after the 31st of December 2007, can access to the net metering system. **Those installations that make use of the feed-in tariff cannot make use of the net metering system**.

Under AEEG's Decision ARG/elt 74/08, GSE has the role of managing net metering and paying the related **contribution**, which covers part of the charges incurred by the customer for withdrawing electricity from the grid. GSE determines the contribution taking into account: the characteristics of the plant, the contractual conditions between the customer and his/her supplier and the **data** that grid operators and suppliers are required to periodically report to GSE. To know more about the **calculation of the net metering contribution**, refer to AEEG's Decision ARG/elt 74/08.

Eligible plants

Owners of one of more of the following plants may apply for the net metering service:

- RES-E plants with a capacity of up to 20 kW;
- RES-E plants with a capacity of up to 200 kW (commissioned after 31 Dec. 2007);
- high-efficiency CHP plants with a capacity of up to 200 kW.

Compatibility with other support scheme

Net metering is not compatible with the simplified purchase & resale arrangements (ritiro dedicato) and with the all-inclusive feed-in tariff (tariffa onnicomprensiva). ;

More information for Net metering can be found at

http://www.gse.it/GSE_UltimiDocumenti/Ritiro%20e%20scambio/Scambio%20sul%20posto/01%20Normativa/Deliberazione%20ARG_elt%20n.%2074_08%20SPnor.pdf

6.3 Incentives as per MD (Ministerial Decree) of 6 Jul. 2012

6.3.1. Scope of application

The Ministerial Decree of 6 Jul. 2012 establishes new procedures for supporting electricity generation by RES-E plants (other than photovoltaic ones) with a capacity of at least 1 kW.

The incentives covered by the Decree apply to new, totally rebuilt, reactivated, repowered/upgraded or renovated plants which will be commissioned on or after 1 January 2013.

To safeguard investments on projects under completion, the Decree provides that the following plants may apply for support on the terms and conditions specified in the Ministerial Decree of 18 Dec. 2008: i) plants authorized before 11 Jul. 2012 (date of enforcement of the Decree) and commissioned by 30 Apr. 2013; and ii) plants authorized before 11 Jul. 2012, fuelled by waste as per art. 8, para. 4 c) of the Decree and commissioned by 30 Jun. 2013. The feed-in tariffs granted or the multiplicative factors for the green certificates issued to these plants will be decreased as indicated in art. 30, para. 1 of the Decree.

6.3.2. Access to the incentives

The Decree defines four different ways of access to the incentives, depending on plant capacity and type of project (art. 4):

1. Direct access for new, totally rebuilt, reactivated or repowered/upgraded plants with a capacity not exceeding a given limit (art.4, para. 3) and using specific types of sources or for special projects;

2. Enrolment into the Registries of new, totally rebuilt, reactivated or repowered/upgraded plants: i) the ranking position of these plants in the relevant Registry shall not exceed the yearly supportable-capacity quotas (art. 9, para. 4); ii) after the project, their capacity shall exceed the maximum one admissible for direct access to the incentives and not exceed the threshold value beyond which participation in competitive Dutch auctions is required. The responsible party shall file an application with GSE for enrolment into the electronic Registry for the source and type of plant to be supported;

3. Enrolment into the Registries of renovated plants: i) the ranking position of these plants in the relevant Registry shall not exceed the yearly supportable-capacity quotas (art. 17, para. 1); ii) after the renovation project, the capacity of these plants shall exceed the maximum one admissible for direct access. The responsible party shall file an application with GSE for enrolment into the electronic Registry of renovated plants for the source and type of plant to be supported.

4. Awarding of incentives after participation in competitive Dutch auctions (electronic auctions held by GSE) for new, totally rebuilt, reactivated or repowered/upgraded plants: i) the capacity of these plants shall exceeda given threshold (10 MW for hydro plants, 20 MW for geothermal plants and 5 MW for other RES-E plants).

To determine the way of access to the incentives for renovated plants, the capacity to be considered corresponds to the increase in capacity obtained as a result of the project

6.3.3. Types of incentives

The Decree establishes that the support shall be granted for the net electricity generated by the plant and injected into the grid. Therefore, **self-consumed electricity is not eligible for incentives**.

The net electricity generated and injected into the grid is the lower value between the net electricity generated and the electricity actually injected into the grid by the plant.

The Decree provides for two separate support schemes, based on plant capacity, renewable source used and type of plant:

A) all-inclusive feed-in tariff (To) for plants with a capacity of up to 1 MW; this capacity is given by the sum of a base feed-in tariff (Tb) and of premiums (Pr), if any (e.g. high-efficiency CHP, emission reductions, etc.).

To = Tb + Pr.

B) incentive (I) for plants with a capacity of above 1 MW and for those with a capacity of up to 1 MW not opting for the all-inclusive feed-in tariff; this incentive is given by the difference between the base feed-in tariff – increased by the premiums, if any, for which the plant is eligible - and the hourly zonal electricity price (in the zone where the electricity generated by the plant is injected into the grid). The electricity generated by plants benefiting from the incentive (I) remains the property of the producer.

It is worth recalling that the access to the incentives as per the Ministerial Decree of 6 Jul. 2012 is alternative to net metering ("scambio sul posto") and to simplified purchase/resale arrangements ("ritiro dedicato").

6.3.4. Feed-in tariffs

The all-inclusive feed-in tariff (tariffa onnicomprensiva) is a national scheme applicable to **RES-E plants** (excluding solar ones) which have a **nominal real power of less than 1 MW** (200 MW for on-shore wind plants).

The tariff is granted over a period of 15 years, during which its rate remains fixed and based on the amount of electricity fed into the grid, for all plants commissioned by 31 December 2012.

To benefit from this form of support, producers must first ask **GSE** to **qualify their plants as RES-E** ("IAFR – Impianto Alimentato a Fonti Rinnovabili").

The Ministerial Decree of 6 Jul. 2012 identifies the value of the base feed-in tariffs (Tb) for each source, type of plant and capacity class for plants which will be commissioned in 2013. The tariffs will decrease by 2% in each of the subsequent years until 2015, except in case of failure to reach 80% of the yearly capacity quota required for the registries and the auctions (art. 7, para. 1 of the Decree).

This means that, if we build our eolic installation in 2013 the feed-in tariff will be as shown in figure 55. But if we build in in 2014 the feed-in tariff will be 0.291·0.98 = 0.285 €/kWh. This way the feed-in tariff depending on the year of building the turbine would be as following:

Values in €/kWh	Power	2013	2014	2015
Eolic On-shore	Less or equal than 20 KW	0.291	0.285	0.279
	Less or equal than 200KW	0.268	0.263	0.257

The value of the base feed-in tariff is the one applicable upon the date of commissioning of the plant. GSE will award the all-inclusive feed-in tariff or the incentive, calculated from the value of the base feed-in tariff, as of the date of entry into commercial operation of the plant.

For plants commissioned prior to the closing of the period of submission of applications for participating in the Registries or Auctions and whose ranking position in the relevant Registries does not exceed the applicable cost limit, GSE will grant the base feed-in tariff applicable upon the date of closing of the same period.

The Decree also provides for a number of premiums (Pr) on top of the base tariff for plants which meet specific operating requirements (articles 8, 26 and 27, Annex 1, Table 1.1, to the Decree).

The feed-in tariff goes as shown in figure 54 and 55.

As we can see in figure 55, the feed-in tariff for cases 2&3 is of 0.291 €/kWh, meanwhile for case 1 it would be of 0.268 €/kWh.

N.	SOURCE	TARIFF (€cent/kWh)
1	Eolic power (less than 200 kW)	30
3	Geothermal	20
4	Waves	34
5	Hydraulic (different than waves)	22

Figure 54. Feed-in tariffs for the different sources of energy

Feed-in tariff for eolic installations.

Source		Power	Useful life of installation	Feed in tariff
		kW	anni	€/MWh
eolic	On-shore	1<P≤20	20	291
		20<P≤200	20	268
		200<P≤1000	20	149
		1000<P≤5000	20	135
		P>5000	20	127
	Off-shore	1<P≤5000	25	176
		P>5000	25	165

Figure 55. Feed-in tariffs for eolic sources of energy

The rate applies to a portion or all of the energy fed into the grid depending on the type of intervention plant built (new construction, reactivation, renovation and upgrading).

The feed-in tariff represents an alternative to the green certificates scheme and is differentiated by type of source.

6.3.5. Processing and administration fees

The responsible parties applying for incentives as per the Ministerial Decree of 6 Jul. 2012 are held to pay GSE a fee for the processing of their applications. This fee is equal to the sum of a fixed fee - € 100 - and of a variable fee, calculated on the basis of the capacity of the plant, as shown below:

a) € 80.00 for plants with a capacity of above 50 kW and not exceeding 200 kW;

b) € 500.00 for plants with a capacity of above 200 kW and not exceeding 1 MW;

c) € 1,320.00 for plants with a capacity of above 1 MW and not exceeding 5 MW;

d) € 2,200.00 for plants with a capacity of above 5 MW.

The processing fee must be paid upon filing the applications for access to feed-in tariffs, enrolment into the Registries, participation in the Auctioning procedures or enrolment into the Registry of renovated plants.

6.4. RES-E ("IAFR") qualification of plants

The qualification of plants as plants using renewable energy sources **("IAFR" – RES-E**) is a pre-requisite to obtain green certificates (CV) as function of the electric energy produced, or the all-inclusive feed-in tariff (TO) as a function of the electric energy produced and inserted in the grid.

Eligible plants include:

new, upgraded/repowered, totally/partially renovated and reactivated plants that have been commissioned after 1 April 1999;

co-firing plants that have been commissioned before 1 April 1999 and have operated as hybrid plants after such date.

Apart from for a few exceptions specified in the Ministerial Decree of 18 Dec. 2008, photovoltaic plants are not eligible for these forms of support, as they only benefit from the support referred to in the Ministerial Decree of 19 Dec. 2007 (PhotoVoltaic feed-in scheme).

Starting in 2009, under the Ministerial Decree of 18 December 2008, plant owners are required to pay a contribution (based on the average yearly capacity of their plant) to the costs incurred by GSE for the qualification procedure.

Figure 56 shows the fees to pay, depending on the annual media nominal power, to obtain the qualification. In our case, 183€ for the plant of 10kW and 244€ for the rest of them considered in case 1.

Minimum annual average power (MW)	Fixed quote (€)	Variable quote (€)	IVA (22%)	Total (€)
P <= 0,02	150	0	33,0	183,0
0,02 < P <= 0,2	150	50	44,0	244,0
0,2 < P <= 1	150	300	99,0	549,0
1 < P <= 10	150	800	209,0	1.159,0
P > 10	150	1200	297,0	1.647,0

Figure 56. Fees to pay to obtain the RES-E ("IAFR") qualification.

6.5. Green certificates

Green Certificates (GCs) are tradable instruments that GSE grants to qualified renewable-energy power plants (IAFR qualification) which have been commissioned before 31 December 2012 as per Legislative Decree 28/2011.

The number of certificates issued is proportional to the electricity generated by the plant/system and varies depending on the type of renewable source used and of project (new, reactivated, upgraded, renovated system/plant).

The GC support scheme is based on the legislation which requires producers and importers of non-renewable electricity to inject a minimum quota of renewable electricity into the power system every year.

GCs represent proof of compliance with the renewable quota obligation: each GC is conventionally worth 1 MWh of renewable electricity. GCs are valid for three years: those issued in respect of electricity generation in a given year (reference year) may be used towards compliance with the obligation also in the following two years.

To fulfill their obligation, producers and importers may inject renewable electricity into the grid or purchase an equivalent number of GCs from green electricity producers.

The Finance Act 2008 introduced a new method of calculating the offer price of the Green Certificate of the GSE: since 2008 they have placed on the market at a price, referring to the MWh electricity, equal to the difference between 180 €/MWh (reference value) and the average annual value of the sale price of electricity by the Authority for electricity and gas.

How to obtain GCs

Producers may apply for GCs after qualifying their plants as renewable-energy power plants/systems (IAFR).

Producers whose plants/systems have a yearly average nominal capacity not exceeding 1 MW (0.2 MW for wind power plants/systems), excluding solar ones, may exercise the right of option between GCs and the all-inclusive feed-in tariff.

Type and duration of both the Feed-in tariff and the Green Certificates.

For plants that came into operation after the 1st of January 2008 , manufacturers may require the incentive by Green Certificates (CV) or, for plants of average annual rated capacity not higher than 1 MW (200 kW for wind power) and at express request of the manufacturer, through the payment of a feed-in tariff (TO) for a period of 15 years.

Only plants of higher annual average nominal power of 1 kW can access to the incentive mechanisms.

6.6. Certification of generated/imported electricity

On a yearly basis, GSE verifies compliance with the obligation specified in article 11 of Legislative Decree 79/99 (quota obligation).

Obliged parties

By 31 March of each year (n), producers and importers of conventional electricity that are subject to the obligation (electricity > 100 GWh) must submit a self-certification of the data that are required to determine: i) the electricity subject to the obligation in respect of generation and/or imports in the previous year (n-1); and ii) the green certificates (GCs) corresponding to the yearly mandatory quota in respect of generation in the year (n-2).

The renewable electricity to be injected into the power system in compliance with the above mentioned obligation must be generated by RES-E (IAFR) qualified plants.

Exemptions from the obligation are as follows :

- renewable electricity generated in CHP (co-generation) plants;
- renewable electricity imported for the reference year 2011, provided that it is certified by Guarantees of Origin issued by an EU Member State or Norway or Switzerland, in accordance with art. 15 of Directive 2009/28/EC;
- renewable electricity which may count towards the achievement of the national target of 17%, under art. 25 , para. 2 of Legislative Decree 28/2011.

GSE's role

If producers or importers fail to fulfill their obligation or to submit their data (self-certification), GSE will - under the Ministerial Decree of 24 October 2005 – report them to AEEG, which will impose the penalties specified in art. 4, para. 3 of Legislative Decree 387/03.

The number of GCs to be introduced into the national power system is obtained by multiplying the amount of the generated and/or imported electricity, subject to the obligation and exceeding 100 GWh, by the mandatory quota for the reference year.

Mandatory production quote for renewable energy (figure 56)

Reference year	Mandatory quota (%)	Compliance year
2010	6,05%	2011
2011	6,80%	2012
2012	7,55%	2013
2013	5,03%	2014
2014	2,52%	2015
2015	0,00%	2016

FIgure 56. Mandatory quote for renewable energy in Italy

From 2013 onwards as provided by Dlg 28/2011, the quota obligation is reduced equal to zero in 2015.

6.7 White certificate

White certificates, also known as “Energy Efficiency Certificates” (EEC), are tradable instruments giving proof of the achievement of **end-use energy savings** through energy efficiency improvement initiatives and projects. More information can be found at www.gse.it.

CHAPTER 7: ECONOMICAL ANALYSIS FOR RENEWABLE!

Now, in order to start with our economical analysis we need to remember that the load of 4.8kWe to be refrigerated was for dimensioning only. And so, for the economical analysis we need to consider the actual load of the shelter, which was 2.4kW as maximum in summer. The total amount of energy we needed to cover in all the year for the dimensioning was 34 MWhe; and so, for the economical analysis we will use then 17 MWhe.

We'll start by developing the best economical option for the case 1, where batteries are not included. We remember that for this configuration we will associate a feed-in tariff.

In a first approximation, we could analyze what happens with the first year.

Model	Initial cost (€)	Mantainance costs (€)	Other costs (€)	Total cost (€)	Annualy produced power (kWh)	Injected in the grid (kWh)	Gain per year (€)	Total (€)
T20pro	90000	5000	2844	97844	92000	83500	24298.5	75605.25
T30pro	95000	5000	2844	102844	103114	94614	25356.6	79547.2
Aeolos-H 20kW	38190	2000	344	40534	75000	66500	19351.5	23242.25
Aeolos-H 30kW	55360	4000	344	59704	114220	105720	28333	33430.79
Aeolos-H 50kW	93460	5000	344	98804	234820	226320	60653.8	40209.99
WINDTECH 20KW	55000	1000	8044	64044	107600	99100	28838.1	37265.65
WINDTECH 30KW	86000	1000	8044	95044	149000	140500	37654	59449.75
Bonus 23-60	183500	7300	424	191224	294000	285500	76514	116769.8
Largerwey 18-60	158500	8000	424	166924	266640	258140	69181.5	99802.23
Nordtank 21-60	138500	7300	424	146224	251400	242900	65097.2	83186.55
Nordtank 25-60	193500	7300	424	201224	356000	347500	93130	110153.8
VESTAS V17-60	168500	7300	424	176224	302170	293670	78703.6	99580.19
VESTAS V20-60	188500	7300	424	196224	273380	264880	70987.8	127295.9

Due to the lack of information in some of the aspects like maintenance costs in some of the wind turbines, we made an approximation for them with known values of wind turbines. For example:

For the Bonus 23-60 the maintenance cost is 7300 for a wind turbine of approximately 150.000€. Therefore, for the T20/T30 pro models (of around 100.000€) the maintenance cost is about 5000€.

As well, in "other costs" we added the price to pay in order to be able to have the all inclusive feed-in tariff and the IAFR qualification of plants certificate (only for the first year).

For the total cost and the electricity injected in the grid, we considered the hypothesis that we can be 3 days without wind, which in summer would be a load of 2.4KW*24h*3=170kWh. Making another hypothesis as well that we would have this lack of wind around 50 times a year[3], 50*170kWh=8500kWh. This is energy that we need to buy back from the grid when needed at a price rate of 0.1835€/kWh. To this we need to add 500€ for the fixed fee plus the quote for the power in which we are working with.

We can state that:

With the AEOLOS-H 30KW we can produce more energy in a year than a T30pro turbine, and its cost is notoriously lower than the T30pro turbine one. At the end of a first year we can see how for the AEOLOS-H 30kW the balance is only -33.430,79€, instead of the -79.547,20€ for the T30pro. Same reason to discard the T20pro due to its high price.

Nevertheless there it's noteworthy that the company Ropatec has models such as T20proS and T30proS that are able to produce even more energy, but always for a higher price.

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[3]In the UK, demand for electricity is higher in winter than in summer, and so are wind speeds. A report from Denmark noted that their wind power network was without power for 54 days during 2002.

Three reports on the wind variability in the UK issued in 2009, generally agree that variability of wind needs to be taken into account, but it does not make the grid unmanageable; and the additional costs, which are modest, can be quantified.

Same reasoning between Nordtank 25-60 and Bonus 23-60. With Nordtank 25-60 we are spending the first year 110.153,80€ and we are able to produce more energy than the Bonus 23-60, which is more expensive (116.769,80€). Therefore Bonus 23-60 is discarded as well. Same reasoning between Nordtank 25-60 and VESTAS V20-60. With 110.153,80€ we can produce 356MWh in a year, meanwhile with 127.295,90€ we can only produce 273.38MWh a year.

Now, there's a need to make a deeper analysis with the rest of the options since they aren't very clear on which one is the best.

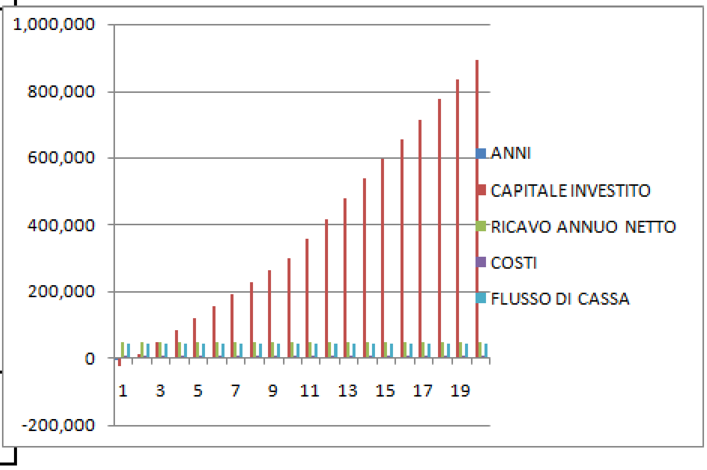
Thanks to the group RENOVA, we are able to develop a more accurate economical analysis with their products. We received from them a very detailed analysis that we will adapt for the rest of the turbines.

We will first start with the Largerwey 18-60. We obtained both a financing plan and a unfunded plan.

BUSINESS PLAN WITH FINANCING

MODEL	LAGERWEY 60
NOMINAL POWER	60 KW
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	258,140
COST	
EOLIC TURBINE COST	110,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	**152,500 €**
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	**6,000 €**
COSTI DI GESTIONE	
Maintenance	2,500 €
All-risk insurance	1,500 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	**10,060 €**
FINANCING RATE (8%)	**23,600 €**
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**69,440 €**

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-23,600 €	69,440 €	33,660 €	35,780 €
2	12,180 €	69,440 €	33,660 €	35,780 €
3	47,960 €	69,440 €	33,660 €	35,780 €
4	83,740 €	69,440 €	33,660 €	35,780 €
5	119,520 €	69,440 €	33,660 €	35,780 €
6	155,300 €	69,440 €	33,660 €	35,780 €
7	191,079 €	69,440 €	33,660 €	35,780 €
8	226,859 €	69,440 €	33,660 €	35,780 €
9	262,639 €	69,440 €	33,660 €	35,780 €
10	298,419 €	69,440 €	33,660 €	35,780 €
11	357,799 €	69,440 €	10,060 €	59,380 €
12	417,179 €	69,440 €	10,060 €	59,380 €
13	476,559 €	69,440 €	10,060 €	59,380 €
14	535,939 €	69,440 €	10,060 €	59,380 €
15	595,319 €	69,440 €	10,060 €	59,380 €
16	654,699 €	69,440 €	10,060 €	59,380 €
17	714,079 €	69,440 €	10,060 €	59,380 €
18	773,458 €	69,440 €	10,060 €	59,380 €
19	832,838 €	69,440 €	10,060 €	59,380 €
20	892,218 €	69,440 €	10,060 €	59,380 €
Total Cashflow				**951,598 €**



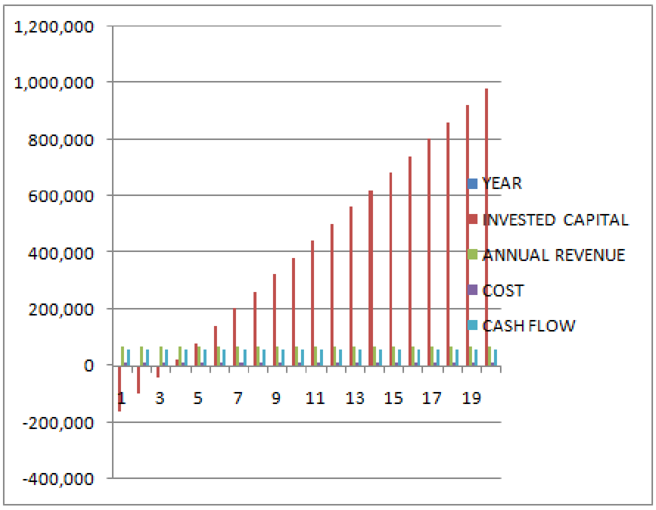
We see from this financial plan that the payback time for the Largerwey 18-60 is 2 years. Also, after 20 years, our initial inversion of 23.600€ would have an approximate revenue of 892.218€.

On the other hand, the financial plan without funding would be:

BUSINESS PLAN WITHOUT FINANCING

MODEL	LAGERWEY 18-60
NOMINAL POWER	60 KW
ANNUAL AVERAGE PRODUCTION	
(ESTIMATED)	
[Kwh]	258,140
COST	
EOLIC TURBINE COST	110,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	152,500 €
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	6,000 €
COSTI DI GESTIONE	
Maintenance	2,500 €
All-risk insurance	800 €
Ground rent	2,000 €
Paid to the grid (for connection & buying)	2,060 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	9,360 €
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	69,440 €

YEAR	INVESTED CAPITAL	ANNUAL REVENU	COST	CASH FLOW
1	-158,500 €	69,440 €	9,360 €	60,080 €
2	-98,420 €	69,440 €	9,360 €	60,080 €
3	-38,340 €	69,440 €	9,360 €	60,080 €
4	21,740 €	69,440 €	9,360 €	60,080 €
5	81,820 €	69,440 €	9,360 €	60,080 €
6	141,900 €	69,440 €	9,360 €	60,080 €
7	201,979 €	69,440 €	9,360 €	60,080 €
8	262,059 €	69,440 €	9,360 €	60,080 €
9	322,139 €	69,440 €	9,360 €	60,080 €
10	382,219 €	69,440 €	9,360 €	60,080 €
11	442,299 €	69,440 €	9,360 €	60,080 €
12	502,379 €	69,440 €	9,360 €	60,080 €
13	562,459 €	69,440 €	9,360 €	60,080 €
14	622,539 €	69,440 €	9,360 €	60,080 €
15	682,619 €	69,440 €	9,360 €	60,080 €
16	742,699 €	69,440 €	9,360 €	60,080 €
17	802,779 €	69,440 €	9,360 €	60,080 €
18	862,858 €	69,440 €	9,360 €	60,080 €
19	922,938 €	69,440 €	9,360 €	60,080 €
20	983,018 €	69,440 €	9,360 €	60,080 €
Totale Flusso di Cassa				1,201,598 €



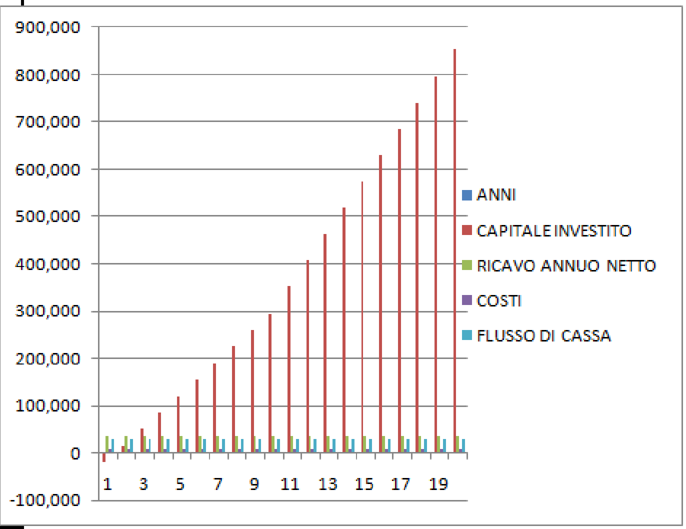
From the plan without financing we can say that the payback time is of 4 years. Also, at the 20th year, our money balance would be clearly advantageous since we would we perceiving a total amount of money (accumulated money among years) of 983.018€. We can also say that, although the initial cost of buying this wind turbine without financing is way higher, at the end, after 20 years, the accumulated money among years is 983.018 against 892.218€ obtained with the financial plan (about 10% more gaining).

For the Nordtank 21-60 we would get:

MODEL	**NORDTANK 21-60**
NOMINAL POWER	**60 KW**
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	242,900
COST	
EOLIC TURBINE COST	90,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	**132,500 €**
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	**6,000 €**
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	**9,360 €**
FINANCING RATE (8%)	**20,640 €**
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**65,097 €**

BUSINESS PLAN WITH FINANCING

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-20,640 €	65,097 €	30,000 €	35,097 €
2	14,457 €	65,097 €	30,000 €	35,097 €
3	49,555 €	65,097 €	30,000 €	35,097 €
4	84,652 €	65,097 €	30,000 €	35,097 €
5	119,750 €	65,097 €	30,000 €	35,097 €
6	154,847 €	65,097 €	30,000 €	35,097 €
7	189,945 €	65,097 €	30,000 €	35,097 €
8	225,042 €	65,097 €	30,000 €	35,097 €
9	260,140 €	65,097 €	30,000 €	35,097 €
10	295,237 €	65,097 €	30,000 €	35,097 €
11	350,975 €	65,097 €	9,360 €	55,737 €
12	406,712 €	65,097 €	9,360 €	55,737 €
13	462,449 €	65,097 €	9,360 €	55,737 €
14	518,187 €	65,097 €	9,360 €	55,737 €
15	573,924 €	65,097 €	9,360 €	55,737 €
16	629,662 €	65,097 €	9,360 €	55,737 €
17	685,399 €	65,097 €	9,360 €	55,737 €
18	741,137 €	65,097 €	9,360 €	55,737 €
19	796,874 €	65,097 €	9,360 €	55,737 €
20	852,612 €	65,097 €	9,360 €	55,737 €
	Totale Flusso di Cassa			**908,349 €**



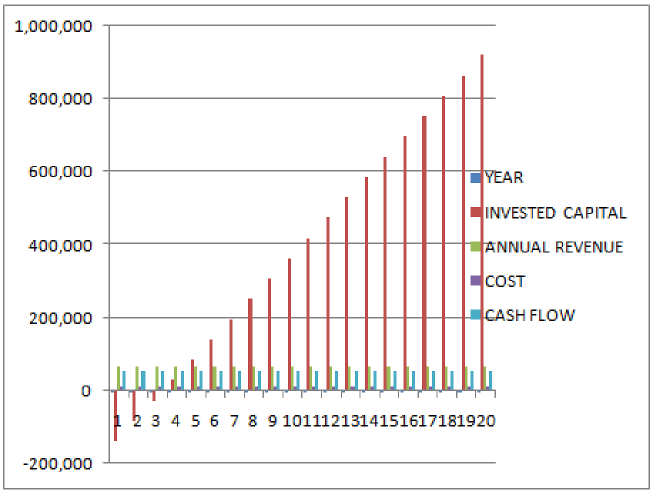
From this financial plan we also see that the payback time for the Nordtank 21-60 is 2 years. After 20 years, our initial inversion of 20.640€ would have an approximate revenue of 852.612€, showing a 30.000€ less than the Largerwey, always with a smaller initial inversion (20.640€ for the Nordtank 21-60, 23.600€ for the Largerwey).

Instead, for the Nordtank 21-60 without financing we gather the following information:

BUSINESS PLAN WITHOUT FINANCING

MODEL	NORDTANK 21-60
NOMINAL POWER	60 KW
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	242,900
COST	
EOLIC TURBINE COST	90,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	**132,500 €**
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	**6,000 €**
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	**9,360 €**
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**65,097 €**

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-138,500 €	65,097 €	9,360 €	55,737 €
2	-82,763 €	65,097 €	9,360 €	55,737 €
3	-27,026 €	65,097 €	9,360 €	55,737 €
4	28,712 €	65,097 €	9,360 €	55,737 €
5	84,449 €	65,097 €	9,360 €	55,737 €
6	140,186 €	65,097 €	9,360 €	55,737 €
7	195,923 €	65,097 €	9,360 €	55,737 €
8	251,660 €	65,097 €	9,360 €	55,737 €
9	307,398 €	65,097 €	9,360 €	55,737 €
10	363,135 €	65,097 €	9,360 €	55,737 €
11	418,872 €	65,097 €	9,360 €	55,737 €
12	474,609 €	65,097 €	9,360 €	55,737 €
13	530,346 €	65,097 €	9,360 €	55,737 €
14	586,084 €	65,097 €	9,360 €	55,737 €
15	641,821 €	65,097 €	9,360 €	55,737 €
16	697,558 €	65,097 €	9,360 €	55,737 €
17	753,295 €	65,097 €	9,360 €	55,737 €
18	809,032 €	65,097 €	9,360 €	55,737 €
19	864,770 €	65,097 €	9,360 €	55,737 €
20	920,507 €	65,097 €	9,360 €	55,737 €
Totale Flusso di Cassa				**1,114,744 €**



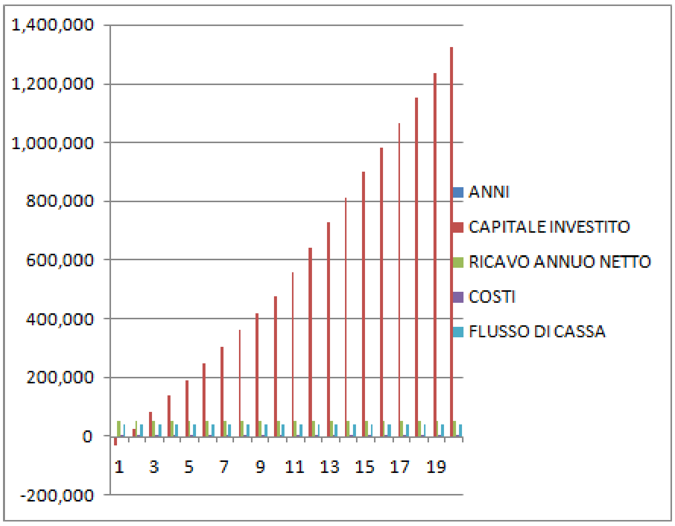
Though the obvious higher initial cost for this option rather than with financing we still have a payback time of 4 years, which keeps being very good. At 20 years we would have an accumulated gain of money of 920.507€. Compared with the Largerwey this value is approximately 60.000€ less at 20 years, always for 20.000€ less as initial cost among the two of them (158.500€ for the Largerwey and 138.500€ for the Nordtank 21-60).

For the <u>Nordtank 25-60</u> we have a financial plan with financing as follows:

BUSINESS PLAN WITH FINANCING

MODEL	NORDTANK 25-60
NOMINAL POWER	60 KW
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	347,500
COST	
EOLIC TURBINE COST	145,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	187,500 €
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	6,000 €
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	9,360 €
FINANCING RATE (8%)	28,837 €
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	93,130 €

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-28,837 €	93,130 €	38,197 €	54,933 €
2	26,096 €	93,130 €	38,197 €	54,933 €
3	81,030 €	93,130 €	38,197 €	54,933 €
4	135,963 €	93,130 €	38,197 €	54,933 €
5	190,896 €	93,130 €	38,197 €	54,933 €
6	245,829 €	93,130 €	38,197 €	54,933 €
7	300,763 €	93,130 €	38,197 €	54,933 €
8	355,696 €	93,130 €	38,197 €	54,933 €
9	410,629 €	93,130 €	38,197 €	54,933 €
10	465,562 €	93,130 €	38,197 €	54,933 €
11	549,333 €	93,130 €	9,360 €	83,770 €
12	633,103 €	93,130 €	9,360 €	83,770 €
13	716,873 €	93,130 €	9,360 €	83,770 €
14	800,643 €	93,130 €	9,360 €	83,770 €
15	884,414 €	93,130 €	9,360 €	83,770 €
16	968,184 €	93,130 €	9,360 €	83,770 €
17	1,051,954 €	93,130 €	9,360 €	83,770 €
18	1,135,724 €	93,130 €	9,360 €	83,770 €
19	1,219,495 €	93,130 €	9,360 €	83,770 €
20	1,303,265 €	93,130 €	9,360 €	83,770 €
Totale Flusso di Cassa				1,387,035 €



Payback time: 2 years as well

Accumulated money among 20 years: 1.303.265€.

This amount of money is clearly bigger than those obtained with Largerwey or Nordtank 21-60. Always for a little higher initial cost: 28.837€.

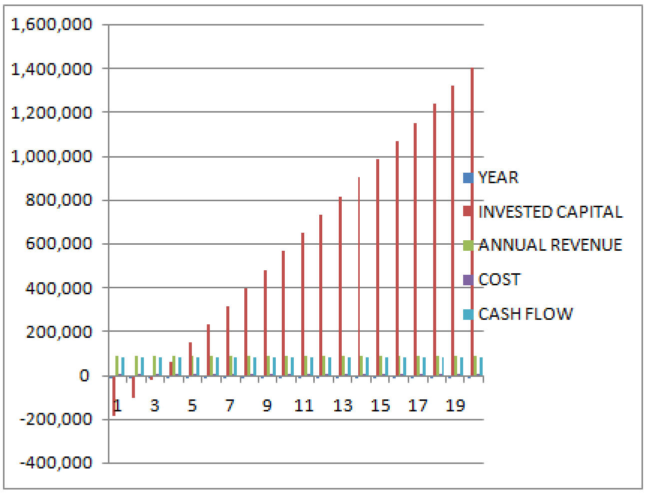
This is so far among the best options.

Meanwhile, without a financing plan we have:

BUSINESS PLAN WITHOUT FINANCING

MODEL	**NORDTANK 25-60**
NOMINAL POWER	**60 KW**
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	347,500
COST	
EOLIC TURBINE COST	135,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	177,500 €
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	6,000 €
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	9,360 €
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**93,130 €**

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-183,500 €	93,130 €	9,360 €	83,770 €
2	-99,730 €	93,130 €	9,360 €	83,770 €
3	-15,960 €	93,130 €	9,360 €	83,770 €
4	67,810 €	93,130 €	9,360 €	83,770 €
5	151,580 €	93,130 €	9,360 €	83,770 €
6	235,350 €	93,130 €	9,360 €	83,770 €
7	319,120 €	93,130 €	9,360 €	83,770 €
8	402,890 €	93,130 €	9,360 €	83,770 €
9	486,660 €	93,130 €	9,360 €	83,770 €
10	570,430 €	93,130 €	9,360 €	83,770 €
11	654,200 €	93,130 €	9,360 €	83,770 €
12	737,970 €	93,130 €	9,360 €	83,770 €
13	821,740 €	93,130 €	9,360 €	83,770 €
14	905,510 €	93,130 €	9,360 €	83,770 €
15	989,280 €	93,130 €	9,360 €	83,770 €
16	1,073,050 €	93,130 €	9,360 €	83,770 €
17	1,156,820 €	93,130 €	9,360 €	83,770 €
18	1,240,590 €	93,130 €	9,360 €	83,770 €
19	1,324,360 €	93,130 €	9,360 €	83,770 €
20	1,408,130 €	93,130 €	9,360 €	83,770 €
Totale Flusso di Cassa				**1,675,400 €**



Always showing a payback time of 4 years. Accumulative gain among 20 years is about 1.408.130€, around 100.000€ more than with financing, but always with the need of making a strong initial inversion (183.500€ against 28.837€).

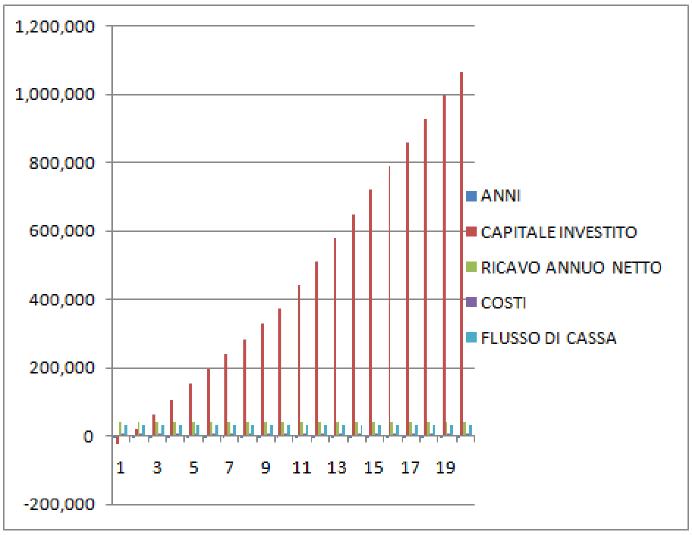
In comparison with the Largerwey or the Nordtank 21-60 without financing, this one shows to be among the best options.

Analysis for <u>VESTAS V17-60</u>:

MODEL	**VESTAS V17-60**
NOMINAL POWER	**60 KW**
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	293,670
COST	
EOLIC TURBINE COST	120,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	**162,500 €**
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	**6,000 €**
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	**9,360 €**
FINANCING RATE (8%)	**25,100 €**
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**78,704 €**

BUSINESS PLAN WITH FINANCING

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-25,100 €	78,704 €	34,460 €	44,244 €
2	19,144 €	78,704 €	34,460 €	44,244 €
3	63,388 €	78,704 €	34,460 €	44,244 €
4	107,631 €	78,704 €	34,460 €	44,244 €
5	151,875 €	78,704 €	34,460 €	44,244 €
6	196,119 €	78,704 €	34,460 €	44,244 €
7	240,363 €	78,704 €	34,460 €	44,244 €
8	284,607 €	78,704 €	34,460 €	44,244 €
9	328,850 €	78,704 €	34,460 €	44,244 €
10	373,094 €	78,704 €	34,460 €	44,244 €
11	442,438 €	78,704 €	9,360 €	69,344 €
12	511,782 €	78,704 €	9,360 €	69,344 €
13	581,126 €	78,704 €	9,360 €	69,344 €
14	650,470 €	78,704 €	9,360 €	69,344 €
15	719,813 €	78,704 €	9,360 €	69,344 €
16	789,157 €	78,704 €	9,360 €	69,344 €
17	858,501 €	78,704 €	9,360 €	69,344 €
18	927,845 €	78,704 €	9,360 €	69,344 €
19	997,189 €	78,704 €	9,360 €	69,344 €
20	1,066,532 €	78,704 €	9,360 €	69,344 €
Totale Flusso di Cassa				**1,135,876 €**



Payback time: Always 2 years.

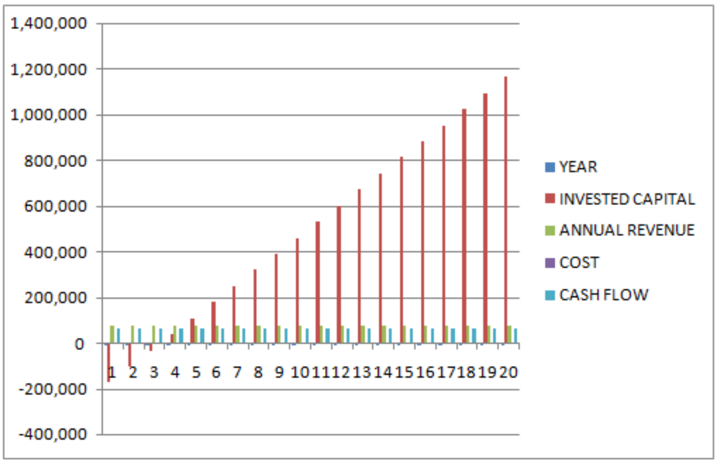
Accumulative gain at 20 years: 1.066.532€.

Same VESTAS V17-60 without a financing plan:

MODEL	**VESTAS V17-60**
NOMINAL POWER	**60 KW**
ANNUAL AVERAGE PRODUCTION	
(ESTIMATED)	0.00
[Kwh]	293,670
COST	
EOLIC TURBINE COST	120,000 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	162,500 €
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	6,000 €
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	9,360 €
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**78,704 €**

BUSINESS PLAN WITHOUT FINANCING

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-168,500 €	78,704 €	9,360 €	69,344 €
2	-98,069 €	78,704 €	9,360 €	69,344 €
3	-27,638 €	78,704 €	9,360 €	69,344 €
4	42,793 €	78,704 €	9,360 €	69,344 €
5	113,225 €	78,704 €	9,360 €	69,344 €
6	183,656 €	78,704 €	9,360 €	69,344 €
7	254,087 €	78,704 €	9,360 €	69,344 €
8	324,518 €	78,704 €	9,360 €	69,344 €
9	394,949 €	78,704 €	9,360 €	69,344 €
10	465,380 €	78,704 €	9,360 €	69,344 €
11	535,812 €	78,704 €	9,360 €	69,344 €
12	606,243 €	78,704 €	9,360 €	69,344 €
13	676,674 €	78,704 €	9,360 €	69,344 €
14	747,105 €	78,704 €	9,360 €	69,344 €
15	817,536 €	78,704 €	9,360 €	69,344 €
16	887,967 €	78,704 €	9,360 €	69,344 €
17	958,398 €	78,704 €	9,360 €	69,344 €
18	1,028,830 €	78,704 €	9,360 €	69,344 €
19	1,099,261 €	78,704 €	9,360 €	69,344 €
20	1,169,692 €	78,704 €	9,360 €	69,344 €
Total Cashflow				**1,386,876 €**



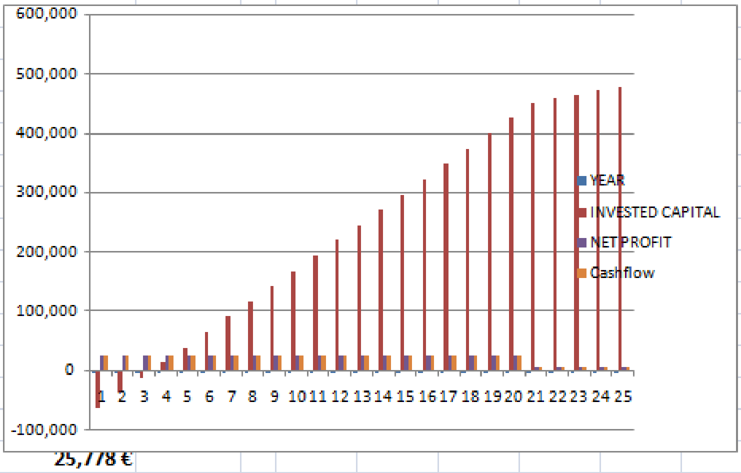
VESTAS V17-60 without financing shows a payback time of 4 years. It also shows a very high accumulated gain after 20 years of 1.169.692€. For just 10.000€ more initial inversion than the Largerwey we can get around 150.000€ more after 20 years with this eolic wind turbine. But, although it is 15.000€ cheaper than the Nordtank 25-60, we are receiving around 250.000€ less after 20 years than this last one.

We will keep now with Renova Company, but now we will analyze a different gamma products among them. First of all, we have the WINDTECH 20KW. Building its respective economical analysis without funding we obtain:

WINDTECH 20 KW

MODEL		WINDTECH - 20 KW	
NOMINAL POWER		20 KW	
PLANT COST (WITHOUT FINANCING)			62,700 €
ANNUAL ESTIMATED AVERAGE PRODUCTION			
AVERAGE ANNUAL POWER		99,100.00	KWh / YEAR
ANNUAL AVERAGE GAIN WITH FEED-IN TARIFF		28,838 €	
0.29 €			
ANNUAL AVERAGE GAIN WITH STANDARD TARIFF AFTER THE 20TH YEAR			
0.10 €		€ 9,910	
ANNUAL MAINTENANCE		€ 1,000	
Paid to the grid (for connection & buying)		€ 2,060	

YEAR	INVESTED CAPITAL	NET PROFIT	Cashflow
1	-€ 62,700	25,778 €	25,778 €
2	-€ 36,922	25,778 €	25,778 €
3	-€ 11,144	25,778 €	25,778 €
4	€ 14,634	25,778 €	
5	€ 40,412	25,778 €	
6	€ 66,190	25,778 €	
7	€ 91,968	25,778 €	
8	€ 117,746	25,778 €	
9	€ 143,524	25,778 €	
10	€ 169,302	25,778 €	
11	€ 195,080	25,778 €	
12	€ 220,858	25,778 €	
13	€ 246,636	25,778 €	
14	€ 272,414	25,778 €	
15	€ 298,192	25,778 €	
16	€ 323,970	25,778 €	
17	€ 349,748	25,778 €	
18	€ 375,526	25,778 €	25,778 €
19	€ 401,304	25,778 €	25,778 €
20	€ 427,082	25,778 €	25,778 €
21	€ 452,860	6,850 €	6,850 €
22	€ 459,710	6,850 €	6,850 €
23	€ 466,560	6,850 €	6,850 €
24	€ 473,410	6,850 €	6,850 €
25	€ 480,260	6,850 €	6,850 €



Payback time: 4 years.

Accumulated gain after 20 years: 427.082€.

This is the first model we analyze with a lower capacity than 60KW. In concrete, with this wind turbine we won't have as much revenue as with others, due to the lower quantity of energy injected in the grid. Nevertheless, its price is more assumable than others, and still we can get on gain approximately the same amount as the invested at the 6th year.

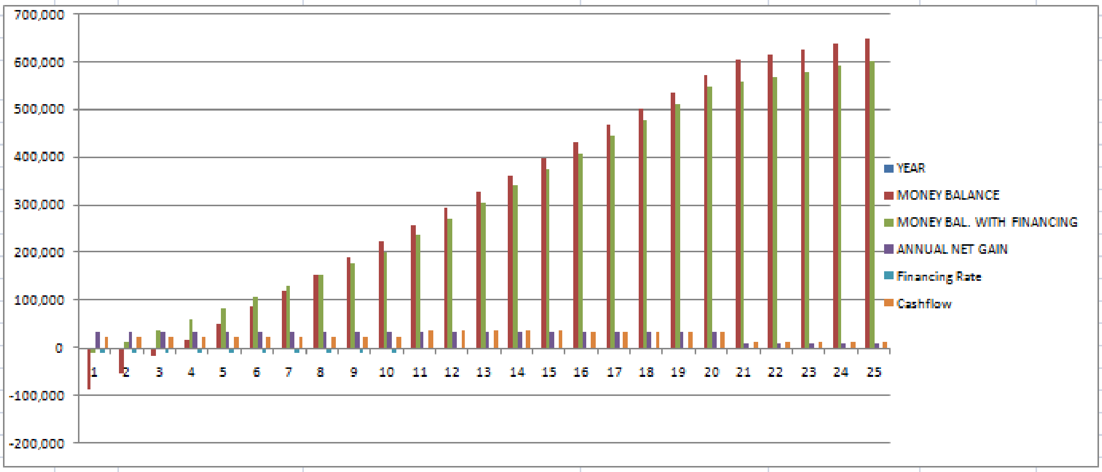
Instead for the <u>WINDTECH 30KW</u> (both financing and without it) we get:

WINDTECH 30 KW

MODEL	WINDTECH - 30 KW
NOMINAL POWER	30 KW
PLANT COST (WITHOUT FINANCING)	86,000 €
ANNUAL ESTIMATED AVERAGE PRODUCTION	
AVERAGE ANNUAL POWER	140,500.00 KWh / year
ANNUAL AVERAGE GAIN WITH FEED-IN TARIFF	37,654 €
0.27 €	
ANNUAL AVERAGE GAIN WITH STANDARD TARIFF AFTER THE 20TH YEAR	
0.10 € €	€ 14,050
ANNUAL MAINTENANCE	€ 1,000
Paid to the grid (for connection & buying)	€ 2,060
ANNUAL FINANCIAL RATE	10,927 €

Financing years: 10 anni
Financial interests: TAEG 5,34
FIXED REAL RATE

YEAR	MONEY BALANCE	MONEY BAL. WITH FINANCING	ANNUAL NET GAIN	Financing Rate	Cashflow
1	-€ 86,000	-10,927 €	34,594 €	-€ 10,927	23,667 €
2	-€ 51,406	12,740 €	34,594 €	-€ 10,927	23,667 €
3	-€ 16,812	36,407 €	34,594 €	-€ 10,927	23,667 €
4	€ 17,782	60,074 €	34,594 €	-€ 10,927	23,667 €
5	€ 52,376	83,741 €	34,594 €	-€ 10,927	23,667 €
6	€ 86,970	107,408 €	34,594 €	-€ 10,927	23,667 €
7	€ 121,564	131,075 €	34,594 €	-€ 10,927	23,667 €
8	€ 156,158	154,742 €	34,594 €	-€ 10,927	23,667 €
9	€ 190,752	178,409 €	34,594 €	-€ 10,927	23,667 €
10	€ 225,346	202,076 €	34,594 €	-€ 10,927	23,667 €
11	€ 259,940	236,670 €	34,594 €	€ 0	36,654 €
12	€ 294,534	271,264 €	34,594 €	€ 0	36,654 €
13	€ 329,128	305,858 €	34,594 €	€ 0	36,654 €
14	€ 363,722	340,452 €	34,594 €	€ 0	36,654 €
15	€ 398,316	375,046 €	34,594 €	€ 0	36,654 €
16	€ 432,910	409,640 €	34,594 €	€ 0	34,594 €
17	€ 467,504	444,234 €	34,594 €	€ 0	34,594 €
18	€ 502,098	478,828 €	34,594 €	€ 0	34,594 €
19	€ 536,692	513,422 €	34,594 €	€ 0	34,594 €
20	€ 571,286	548,016 €	34,594 €	€ 0	34,594 €
21	€ 605,880	559,006 €	10,990 €	€ 0	13,050 €
22	€ 616,871	569,996 €	10,990 €	€ 0	13,050 €
23	€ 627,861	580,986 €	10,990 €	€ 0	13,050 €
24	€ 638,851	591,976 €	10,990 €	€ 0	13,050 €
25	€ 649,841	602,966 €	10,990 €	€ 0	13,050 €



Results with same tendency as WINDTECH 20 KW, but as obvious with a lightly bigger initial cost, revenue, annual net gain due to its higher power.

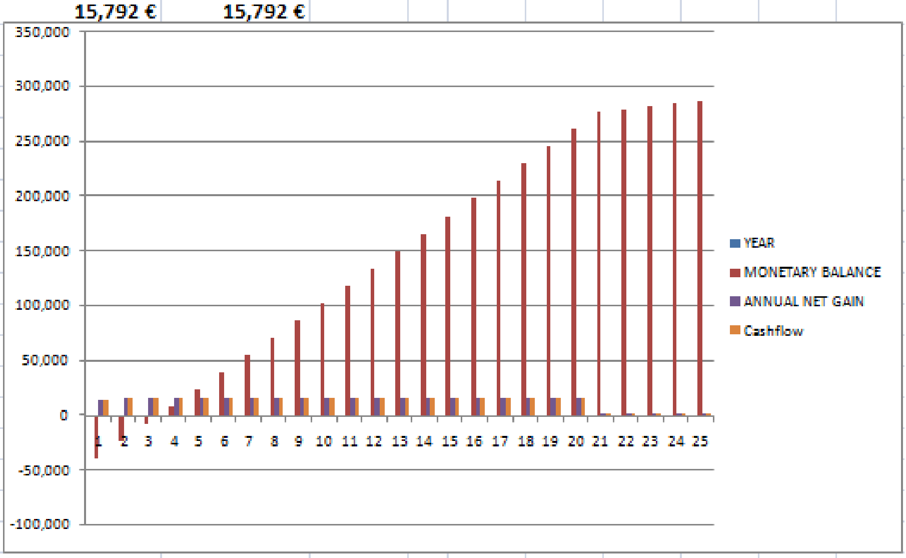
And finally, we made same approximations due to the lack of information for the AEOLOS-H 20, 30 & 50 kW. Only economical analysis without funding could be made.

For AEOLOS-H 20KW we have:

AEOLOS-H 20 KW

MODEL		AEOLOS-H 20 KW	
NOMINAL POWER		20 KW	
PLANT COST (WITHOUT FINANCING)			38,190 €
ANNUAL ESTIMATED AVERAGE PRODUCTION			
AVERAGE ANNUAL POWER		66,500.00	KWh / year
ANNUAL AVERAGE GAIN WITH FEED-IN TARIFF		19,352 €	
0.29 €			
ANNUAL AVERAGE GAIN WITH STANDARD TARIFF AFTER THE 20TH YEAR			
0.10 € €		€ 6,650	
ANNUAL MAINTENANCE		€ 2,000	
Paid to the grid (for connection & buying)		€ 2,060	

YEAR	MONETARY BALANCE	ANNUAL NET GAIN	Cashflow
1	-€ 38,190	15,292 €	15,292 €
2	-€ 22,898	15,792 €	15,792 €
3	-€ 7,106		
4	€ 8,686		
5	€ 24,478		
6	€ 40,270		
7	€ 56,062		
8	€ 71,854		
9	€ 87,646		
10	€ 103,438		
11	€ 119,230		
12	€ 135,022		
13	€ 150,814		
14	€ 166,606		
15	€ 182,398		
16	€ 198,190		
17	€ 213,982		
18	€ 229,774		
19	€ 245,566		
20	€ 261,358	15,792 €	15,792 €
21	€ 277,150	2,590 €	2,590 €
22	€ 279,740	2,590 €	2,590 €
23	€ 282,330	2,590 €	2,590 €
24	€ 284,920	2,590 €	2,590 €
25	€ 287,510	2,590 €	2,590 €



Payback time: 4 years.

Accumulated gain at 20 years: 261.358€.

Compared to WINDTECH 20KW we have a lower initial cost (38.200€ vs. 62.700€). Nevertheless, the accumulated gain at 20 years for the WINDTECH 20KW goes up to 427.000€.

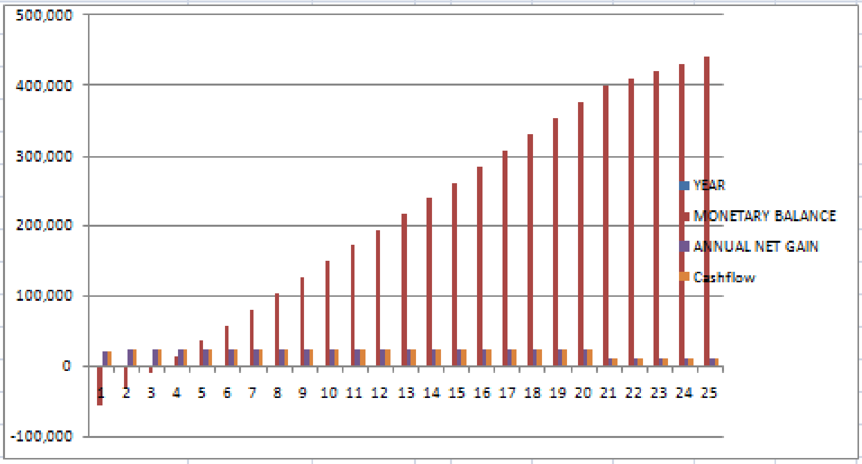
We can say that for almost the double of price, we can gain double the amount of money for this comparison between the two 20KW models.

For AEOLOS-H 30KW:

AEOLOS-H 30 KW

MODEL	AEOLOS-H 30 KW	
NOMINAL POWER	20 KW	
PLANT COST (WITHOUT FINANCING)		55,360 €
ANNUAL ESTIMATED AVERAGE PRODUCTION		
AVERAGE ANNUAL POWER	105,720.00	KWh
ANNUAL AVERAGE GAIN WITH FEED-IN TARIFF	28,333 €	
0.27 €		
ANNUAL AVERAGE GAIN WITH STANDARD TARIFF AFTER THE 20TH YEAR		
0.10 €	€ 10,572	
ANNUAL MAINTENANCE	€ 4,000	
Paid to the grid (fixed fee + buying)	€ 2,060	

YEAR	MONETARY BALANCE	ANNUAL NET GAIN	Cashflow
1	-€ 55,360	22,273 €	22,273 €
2	-€ 33,087	22,773 €	22,773 €
3	-€ 10,314		
4	€ 12,459		
5	€ 35,232		
6	€ 58,005		
7	€ 80,778		
8	€ 103,551		
9	€ 126,324		
10	€ 149,097		
11	€ 171,870		
12	€ 194,643		
13	€ 217,416		
14	€ 240,189		
15	€ 262,962		
16	€ 285,735		
17	€ 308,508	22,773 €	22,773 €
18	€ 331,281	22,773 €	22,773 €
19	€ 354,054	22,773 €	22,773 €
20	€ 376,827	22,773 €	22,773 €
21	€ 399,600	10,572 €	10,572 €
22	€ 410,172	10,572 €	10,572 €
23	€ 420,744	10,572 €	10,572 €
24	€ 431,316	10,572 €	10,572 €
25	€ 441,888	10,572 €	10,572 €



Payback time: 4 years:

Gain after 20 years: 376.827€.

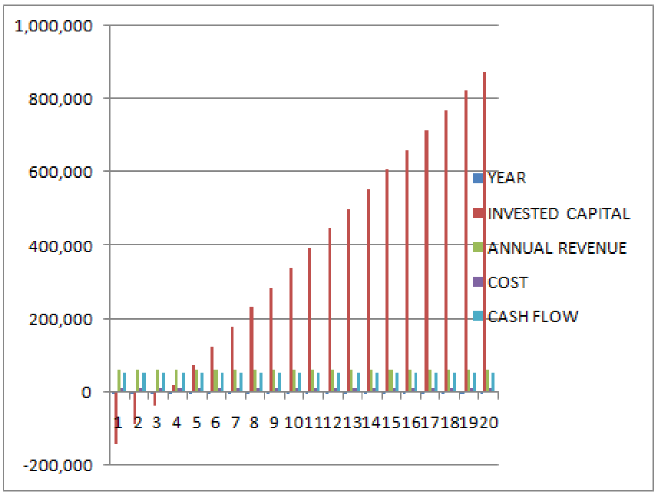
With respect to the WINDTECH 20KW, for a little less than 20.000€ as initial inversion, we would get around 100.000€ more in Brindisi for this wind turbine than the last one.

And finally for the AEOLOS-H 50KW:

BUSINESS PLAN WITHOUT FINANCING

MODEL	**AEOLOS-H 50KW**
NOMINAL POWER	**50 KW**
ANNUAL AVERAGE PRODUCTION (ESTIMATED) [Kwh]	234,820
COST	
EOLIC TURBINE COST	93,460 €
Installation	3,500 €
Nolo Gru	5,000 €
Connection Cost	
Tica	5,000 €
Authorization Cost	
Engineering Cost	
Work Dir.	
Test	
Site safety	
Gse	
Utf	
Fine lavori enel	
Total engineering cost	5,000 €
COST OF ELECTRIC WORKS	
Foundation	16,000 €
Electrical Works	3,000 €
Interfase CEI 021	5,000 €
TOTAL PLANT COST	**135,960 €**
ACCESSORIES COST	
Leasehold	3,500 €
Constitution srl	2,500 €
TOTAL COST FOR ACCESSORIES	**6,000 €**
Management cost	
Maintenance	2,500 €
All-risk insurance	800 €
Paid to the grid (for connection & buying)	2,060 €
Ground rent	2,000 €
Management cost srl	2,000 €
TOTAL MANAGEMENT COST	**9,360 €**
RICAVI	
Feed in tariff	0.27 €
ANNUAL AVERAGE GAIN	**62,932 €**

YEAR	INVESTED CAPITAL	ANNUAL REVENUE	COST	CASH FLOW
1	-141,960 €	62,932 €	9,360 €	53,572 €
2	-88,388 €	62,932 €	9,360 €	53,572 €
3	-34,816 €	62,932 €	9,360 €	53,572 €
4	18,755 €	62,932 €	9,360 €	53,572 €
5	72,327 €	62,932 €	9,360 €	53,572 €
6	125,899 €	62,932 €	9,360 €	53,572 €
7	179,471 €	62,932 €	9,360 €	53,572 €
8	233,042 €	62,932 €	9,360 €	53,572 €
9	286,614 €	62,932 €	9,360 €	53,572 €
10	340,186 €	62,932 €	9,360 €	53,572 €
11	393,758 €	62,932 €	9,360 €	53,572 €
12	447,329 €	62,932 €	9,360 €	53,572 €
13	500,901 €	62,932 €	9,360 €	53,572 €
14	554,473 €	62,932 €	9,360 €	53,572 €
15	608,045 €	62,932 €	9,360 €	53,572 €
16	661,616 €	62,932 €	9,360 €	53,572 €
17	715,188 €	62,932 €	9,360 €	53,572 €
18	768,760 €	62,932 €	9,360 €	53,572 €
19	822,332 €	62,932 €	9,360 €	53,572 €
20	875,903 €	62,932 €	9,360 €	53,572 €
Total Cashflow				**1,071,435 €**



For this wind turbine we have a payback time as well of 4 years. Its obvious initial cost (141.960€) is higher than their previous models, but as well, as logic, with a Grid on configuration and the Feed-in tariff, will allow this wind turbine to inject more energy to the grid, and therefore, to have more revenue over all years.

After seeing the results of this economical analysis for case 1 we can build the following chart:

Model	Initial Cost (€)	Payback time (years)	Gain per year (€) (until 10 years)	Gain at 15 years (€)	(Gain at 15 years/Initial cost)
Largerwey 18-60 (60kW)	23600	2	35780	595319	2522.53814
	158500	4	60080	682619	430.674448
Nordtank 21-60 (60KW)	20640	2	35097	573924	2780.63953
	138500	4	55737	641821	463.408664
Nordtank 25-60 (60 KW)	28837	2	54933	884414	3066.94178
	183500	4	83770	989280	539.117166
VESTAS V17-60 (60KW)	25100	2	44244	719813	2867.78088
	168500	4	69344	817536	485.18457
WINDTECH 20 KW	62700	4	25778	298192	475.585327
WINDTECH 30 KW	10927	2	23667	375046	3432.287
	86000	4	34594	398316	463.15814
AEOLOS-H 20KW	38190	4	15292	182398	477.606703
AEOLOS-H 30KW	55360	4	22573	262962	475.003613
AEOLOS-H 50KW	141960	4	53572	608045	428.321358

As we can see, all the technologies have the same payback time. There's a need to say that typically all of them have an approximate life time of 20 years, even though most of their guarantees are for 5 years. We created, in order to compare, a coefficient between the economical gain at 15 years and the initial cost for each of the turbines. This way, the higher the coefficient the better, but of course at the end is the company which will finally evaluate their budget for the project.

Regarding with this coefficient, the Nordtank 25-60 and the WINDTECH 30KW with funding are among the best options in the market. If we are looking instead for a funding program, the Nordtank 25-60 is the best option due to its higher comparative coefficient among those with funding.

On the other hand, for cases 2 and 3 we need to say that still our plant will supply a load of 17MWh when it was designed to supply at least 34MWh. This means that, until the load is not doubled we will still use the all inclusive feed-in tariff for case 2.

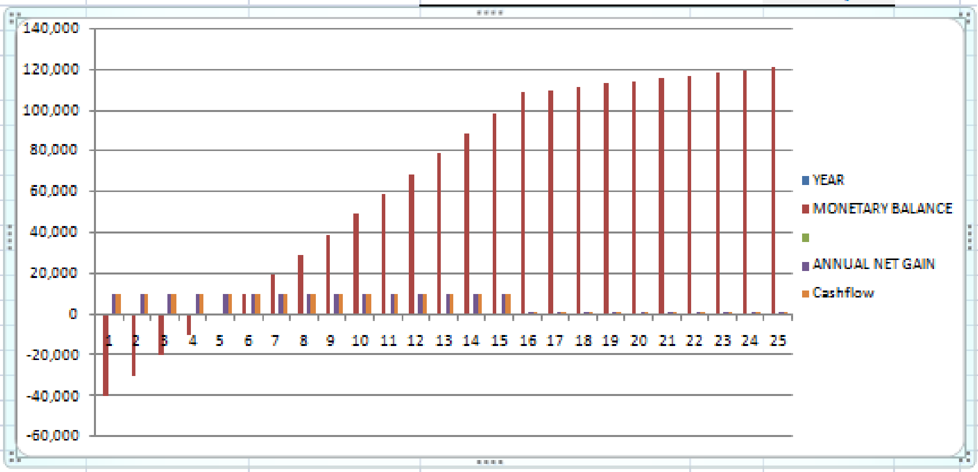
For case 2:

To analyze cases 2 and 3 we will start with the AEOLOS-H 10KW:

AEOLOS-H 10KW

MODEL		AEOLOS 10 KW
NOMINAL POWER		10 KW
COST OF THE TURNKEY PROJECT WITH 10% IVA (WITHOUT FUNDING)		€ 40,000.00
ANNUAL ESTIMATED PRODUCTION		44,500 KWh
ANNUAL AVERAGE GAIN WITH FEED-IN TARIFF	€ 0.29	€ 12,950
ANNUAL AVERAGE GAIN WITH STANDARD TARIFF AFTER THE 15TH YEAR	€ 0.10	€ 4,450
ANNUAL MAINTENANCE + Paid to the grid (fixed fee & buying)		€ 3,060

YEAR	MONETARY BALANCE	ANNUAL NET GAIN	Cashflow
1	-€ 40,000	9,890 €	9,890 €
2	-€ 30,110	9,890 €	9,890 €
3	-€ 20,221	9,890 €	9,890 €
4	-€ 10,331	9,890 €	9,890 €
5	-€ 441	9,890 €	9,890 €
6	€ 9,449	9,890 €	9,890 €
7	€ 19,339	9,890 €	9,890 €
8	€ 29,228	9,890 €	9,890 €
9	€ 39,118	9,890 €	9,890 €
10	€ 49,008	9,890 €	9,890 €
11	€ 58,898	9,890 €	9,890 €
12	€ 68,787	9,890 €	9,890 €
13	€ 78,677	9,890 €	9,890 €
14	€ 88,567	9,890 €	9,890 €
15	€ 98,457	9,890 €	9,890 €
16	€ 108,346	1,390 €	1,390 €
17	€ 109,737	1,390 €	1,390 €
18	€ 111,127	1,390 €	1,390 €
19	€ 112,517	1,390 €	1,390 €
20	€ 113,907	1,390 €	1,390 €
21	€ 115,298	1,390 €	1,390 €
22	€ 116,688	1,390 €	1,390 €
23	€ 118,078	1,390 €	1,390 €
24	€ 119,468	1,390 €	1,390 €
25	€ 120,859	1,390 €	1,390 €
		Total cashflow	€ 162,249



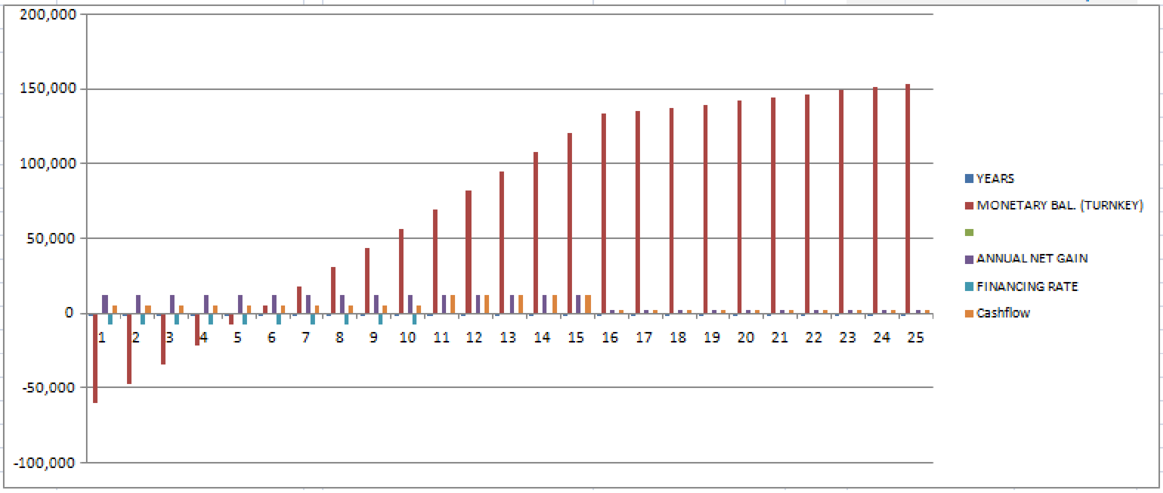
On the other hand, for the MISTRAL 10KW:

MISTRAL 10KW

MODEL		MISTRAL 10 KW with 12 mt. Tower
NOMINAL POWER		10 KW
COST OF THE TURNKEY PROJECT WITH 10% IVA (WITHOUT FUNDING)		€ 59,080.00
ANNUAL ESTIMATED PRODUCTION		53,000 KWh
ANNUAL AVERAGE GAIN WITH FEED-IN TARIFF	€ 0.30	€ 15,900
ANNUAL AVERAGE GAIN WITH STANDARD TARIFF AFTER THE 15TH YEAR	€ 0.10	€ 5,300
ANNUAL MAINTENANCE + Paid to the grid (fixed fee & buying)		€ 3,060
FINANCING RATE	€ 7,506	

Years of financing: 10 anni
Financing rate: TAEG 5,34
TASSO FISSO REALE 3,61 %

YEARS	MONETARY BAL. (TURNKEY)	MONETARY BAL. (FUNDING)	ANNUAL NET GAIN	FINANCING RATE	Cashflow
1	-€ 59,080	-7,506 €	12,840 €	-€ 7,506	5,334 €
2	-€ 46,240	-2,172 €	12,840 €	-€ 7,506	5,334 €
3	-€ 33,400	3,163 €	12,840 €	-€ 7,506	5,334 €
4	-€ 20,559	8,497 €	12,840 €	-€ 7,506	5,334 €
5	-€ 7,719	13,831 €	12,840 €	-€ 7,506	5,334 €
6	€ 5,121	19,165 €	12,840 €	-€ 7,506	5,334 €
7	€ 17,962	24,500 €	12,840 €	-€ 7,506	5,334 €
8	€ 30,802	29,834 €	12,840 €	-€ 7,506	5,334 €
9	€ 43,642	35,168 €	12,840 €	-€ 7,506	5,334 €
10	€ 56,482	40,502 €	12,840 €	-€ 7,506	5,334 €
11	€ 69,323	53,343 €	12,840 €	€ 0	12,840 €
12	€ 82,163	66,183 €	12,840 €	€ 0	12,840 €
13	€ 95,003	79,023 €	12,840 €	€ 0	12,840 €
14	€ 107,843	91,863 €	12,840 €	€ 0	12,840 €
15	€ 120,684	104,704 €	12,840 €	€ 0	12,840 €
16	€ 133,524	106,944 €	2,240 €	€ 0	2,240 €
17	€ 135,764	109,184 €	2,240 €	€ 0	2,240 €
18	€ 138,004	111,424 €	2,240 €	€ 0	2,240 €
19	€ 140,245	113,665 €	2,240 €	€ 0	2,240 €
20	€ 142,485	115,905 €	2,240 €	€ 0	2,240 €
21	€ 144,725	118,145 €	2,240 €	€ 0	2,240 €
22	€ 146,965	120,385 €	2,240 €	€ 0	2,240 €
23	€ 149,206	122,626 €	2,240 €	€ 0	2,240 €
24	€ 151,446	124,866 €	2,240 €	€ 0	2,240 €
25	€ 153,686	127,106 €	2,240 €	€ 0	2,240 €
				Total cashflow (25 years)	€ 139,946



As we did before in <u>case 1</u>, we can build the following results chart:

Model	Initial Cost (€)	Payback time (years)	Gain per year (€) (until 10 years)	Gain at 15 years (€)	(Gain at 15 years/Initial cost)
AEOLOS-H 10KW	40000	6	10790	98457	246.1425
MISTRAL 10KW	59080	6	12840	120684	204.272173
	7506	3	5334	104704	1394.93738

Showing that, without funding the AEOLOS-H 10KW is lightly the best option due to the coefficient and the year less in payback time. We can't compare the funding payments between the two of them due to the lack of information.

In case 3, we will add to our economical analysis the price of the batteries. As well as the price for the configuration to AEOLOS-H 10KW Grid Off changes from the Grid on mode.

On our previous calculations, and thanks to the information given by the company AEOLOS Wind Energy Co., we would make use of **235 units of the 12V, 200Ah lead-acid batteries, at a price of 145$ each of them (≈110**€). This makes a total invest to the project of 25.850€. But since this calculations were made for when the load of the shelter was duplicated (5kW), for the beginning of the project we would only need 118 units at 13.000€. Still this is by now a big amount of money for our application in order to be in a Grid off connection. Especially in countries like Italy where the grid can act as a sort of battery for the application, grabbing from it energy when needed and plugging into it the exceed of production when existing.

Nevertheless, we would need to consider the economical analysis we will develop now to check out from what distance to the grid, the convenience of using batteries instead of using a Grid on configuration is more advantageous (up to 5 years), since the connection to the grid requires a price based on the distance from the telecommunication shelter to the grid.

This price can be seeing in the following chart:

Distance from shelter to the grid	Year 2013
Fixed fee	184,11 €
Added fee to apply, for each 100m or fraction over 50m, from 200m up to 700m	92,29 €
Added fee to apply, for each 100m or fraction over 50m, from 700m up to 1200m	184,11 €
Added fee to apply, for each 100m or fraction over 50m, from 1200m and on	368,22 €

Generating the curve shown in figure 57.

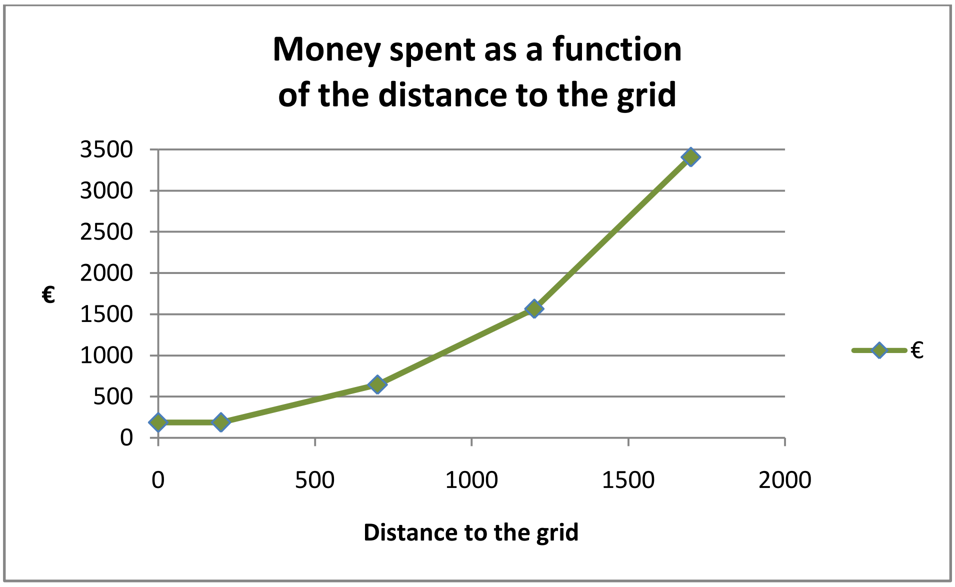


Figure 57. Money spent as a function to the distance of the shelter with the grid connection.

CHAPTER 8: Final Comparison & Conclusion!

It's time to finally evaluate which of the 3 cases is the best, when do they get equalize, and the comparison from using eolic energy and not using anything at all.

The three of the cases will supply an electrical load for a compressor located in a cycle that is shown back in chapter 2, figure 5. Therefore, the price of the rest of the refrigeration system is not contemplated in this analysis.

As we analyzed in the previous chapter, there are different options to cover the electric demand for the application. In order to contrast them we will select the MISTRAL 10KW, for which we have more detailed information among those wind turbines of lower power (covering cases 2 and 3); and the Nordtank 25-60, which is among the best options to cover case 1.

For the MISTRAL 10KW we have a 10KW Wind Turbine with a 12m pillar for a turnkey project with the 10% of IVA with a total price of 59.080,00€. A maintenance annual price of 1.000,00€ plus an annual buying to the network for hypothesized lack of wind of 8.500,00 kWh at 0.1835 €/kWh = 1.600,00€ plus 500€ for grid connection.

Model	Initial Cost (€)	Payback time (years)	Gain per year (€) (until 10 years)	Gain at 15 years (€)	(Gain at 15 years/Initial cost)
MISTRAL 10KW	59080 7506	6 3	12840 5334	120684 104704	204,27 1394.94

For this eolic case, the price of obtaining the energy has been already calculated in chapter 7. Is it going to be cheaper than simply buying the electricity directly from the grid?.

Our application needs 17 MWh/year to produce the cooling that will keep the shelter at 20°C. Buying the electricity directly from the grid would have an annual cost of 17.000kWh*0.1835€/kWh=3120€ plus a fixed fee of 238€ and 268€ for power quote. Approximately 3.650€/year.

As we saw in previous chapter, the payback time for an eolic installation (at the most) is around 6 years with the MISTRAL 10KW. At the end of year 4 we would have still negative values for our balance of -20.559,00€. If we go through 4 years buying electricity from the grid we would have spend 3650*4=14.600,00€ . Meanwhile, at the end of the 5th year, our balance for the MISTRAL 10KW would be of -7.719,00€. Instead, when buying the electricity directly from the grid, the cost of this at the 5th year would be 3650*5=18.250,00€ which is clearly higher than 7.719,00€. **This means that, building our mini-eolic installation (in the worst of the cases) would have its benefits against not building it from the 4th year and on.**

Note: There's an additional initial cost for the connection to the grid, but this cost will be applied for both configurations, so in order to compare them it doesn't represent an important factor to determine which is the best. Later we will make the analysis comparing this initial cost for the connection to the grid and working with a Grid off configuration (based on the distance to the connection with the grid).

Instead, if we choose to buy the MISTRAL 10KW with financing of 7.506,00€ a year, we would be having a payback time of 3 years. Receiving a 4.163,00€ for the third year.

We will do the same for Nordtank 25-60 which has the greater income at the 15th year. This model with financing has a payback time of 2 years, gaining 27.291,00€ at it. Without finance its payback time is 4 year, gaining 76.075€ at it.

Model	Initial Cost (€)	Payback time (years)	Gain per year (€) (until 10 years)	Gain at 15 years (€)	(Gain at 15 years/Initial cost)
NORDTANK 25-60	183500 28837	4 2	83770 54933	989280 884414	539.12 3066.94

Collecting this data as shown in figure 58 we can state that the best option is clearly the Nordtank 25-60. Although it all depends on the amount of money that we would like to spend on the project. **We see that the Nordtank 25-60 with funding has a reasonable initial cost, and they prove to be a very profitable option with their gaining year by year**.

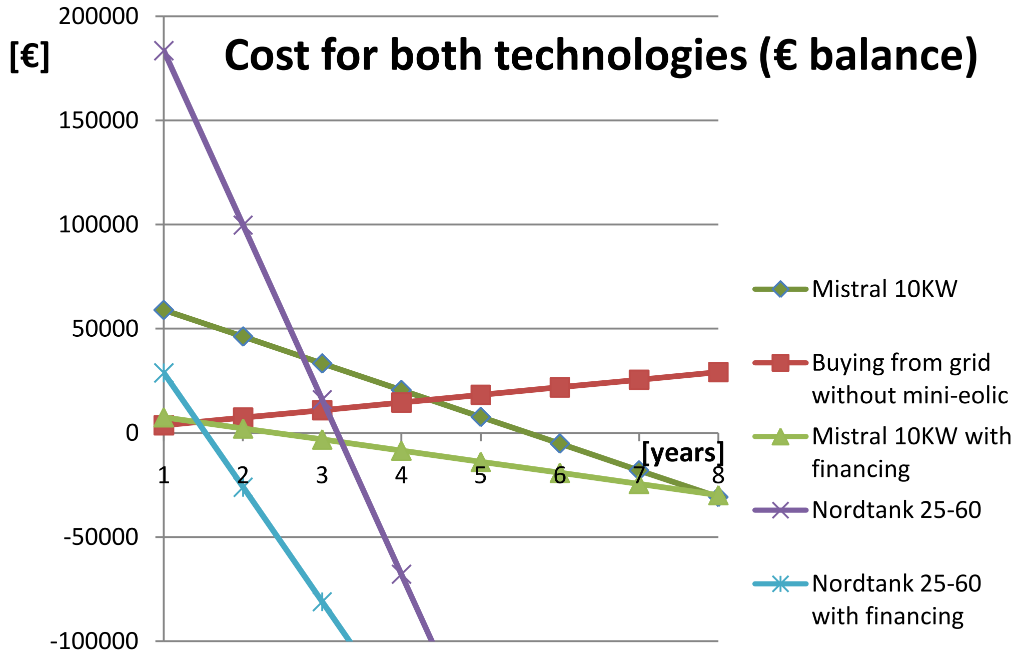


Figure 58. Comparison of all diverse options to finance our project.

As we mentioned before, we will now study from what distance does the Grid off configuration results to be better in economical terms than the grid on one. For this we will take as reference a period of 5 years. As we said in chapter 7, there's a price to pay for the connection to the grid, and it depends on the distance between our shelter and the grid itself.

We then select for the analysis what will happen with the Nordtank 25-60 wind turbine with a financing plan.

In order to obtain this distance we will simply equalize both cost curves to get the limit value.

The cost for using batteries is found at the end of chapter 7, and it's 13.000,00€. To this cost we need to add the value of paying the Mistral 10KW.

Note: In this case we don't use the Nordtank 25-60 since there's no need to produce extra energy to inject to the grid. And so, we choose the best of the lower power options, which is the MISTRAL 10KW.

Therefore, at 5 years, the cost for the Grid off configuration goes as follows:

13.000,00€ + 7.506,00€·5. Where 7.506,00€ is the financing quote for the MISTRAL 10KW.

On the other hand, for our grid on installation after 5 years goes:

1.566,11€ + 368.22€/100m·X - 190.896,00€. Where 1.566,11€ is the value for the connection to the grid at 1200 meters. 368.22€ the cost for each 100 meters above 1200 meters; and 190.896,00€ the profit for the Nordtank 25-60 without funding (worst of the cases) after 5 years (including costs).

For the Grid off configuration being a better option up to 5 years, the following condition should be verified:

$$1.566{,}11€ + \frac{368.22€}{100m} \cdot X - 190.896{,}00€ > 13.000{,}00€ + 7.506{,}00€ \cdot 5$$

X > 65140,4 meters, approximately 65 kms.

Or in other case, with the MISTRAL 10KW without founding

$$1.566{,}11€ + \frac{368.22€}{100m} \cdot X - 190.896{,}00€ > 13.000{,}00€ + 59.080{,}00€$$

X > 70992,85 meters, approximately 71 kms.

This would mean that, if the shelter is located further than 65+1.2 = 66.2 kms or 71+1.2=72.2 kms (in the case of choosing MISTRAL 10KW without funding) from the connection to the grid point, during 5 years the Grid off connection represents a better option than a Grid on connection.

In conclusion:

After realizing the respective analysis, and applying the basic theories of wind energy into the requirements of our project we can finally say that the implementation of this technology with the actual incentive system presented on Italy, is very profitable to cover our refrigeration demand with eolic power. Also, if the budget of the project allows us to, using an even more powerful windturbine (that exceeds our demand) is clearly a good business, thanks to the Feed-in tariff that covers us the payment at a very good rate of 0.3€/kWh. This way, more energy can be injected in the grid and therefore, more revenue for our purpose.

We also studied that Perugia is not a good place for the eolic power, obtaining results of about 5 more times in Brindisi than in Perugia.

As well, the grid off configuration was discarded as useful, especially if the grid connection is close to the position on which we would build our telecommunication shelter (with the eolic turbine). The only condition that the Grid Off configuration could compare to the Grid on configuration after 5 years would be in the case studied on this last chapter (having the closes grid connection at bigger distances than 70 kms).

In addition to this, we can also state that, depending on the budget of the project, among the two best options to cover the demand would be the MISTRAL 10 KW or the Nordtank 25-60. Both wind turbines manufactured by the company RENOVA.

For both cases, obtained results give a positive vision for renewable energies (especially for wind) in Italy. Therefore, refrigeration load can perfectly be covered by renewable energy such as wind, in a very profitable way.

We also need to thank the named companies that supplied their financial plans for their products. Without them, this thesis wouldn't have been possible.

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